ARS SPECIAL REPORT

Radioactive Fallout in Time of Emergency

Effects Upon Agriculture

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Preface

If a nuclear attack were to be made upon the United States, all segments of our population and of our economic structure would be affected. Many of the problems created would be similar if not identical among the various segments. Some of the effects would be peculiar to each segment according to its needs and responsibilities.

Thus, agriculture would share the Nation's total difficulty and still be faced with special problems. The United States Department of Agriculture, in cooperation with other agencies of Federal and State governments, is responsible for helping to develop means by which farm people could cope with these special problems for their own protection and to maintain farm production in times of emergency. In fulfilling its responsibility, the Department participates in devising active defense programs, in conducting research to provide the knowledge on which these programs are based, and in keeping farm people and agricultural leaders informed about them.

One of the major parts of the defense plan being developed against nuclear warfare is aimed at radioactive fallout. This report describes what is known about the effect of fallout on agriculture and what can be done to defend against it.

Some of the terms used may be unfamiliar because the widespread application of nuclear science is relatively new. However, many of them are rapidly becoming a part of the Nation's everyday vocabulary. A glossary is included in this report to aid in a fuller understanding of such terms.

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Radioactive Fallout in Time of Emergency
–Effects Upon Agriculture

The development of nuclear energy has created a new and uncertain element in man's world. On the one hand are the rapidly expanding horizons of progress made possible through the peacetime uses of this new form of energy. On the other hand is the possibility of destruction through the use of nuclear weapons if world peace cannot be maintained. There is also the continuing possibility of accidents resulting from the normal use of nuclear power.

One of the important defenses against widespread destruction from nuclear weapons is a well-informed population, armed with as much knowledge as possible about protection and survival in case of attack. Agricultural leaders and farmers would be responsible in time of an attack for the protection of farm people and the ability of the Nation to produce food and other products necessary for existence.

Research, both public and private, is developing knowledge that would help to provide this protection and the United States Department of Agriculture is taking part. The study of nuclear weapons is a relatively new science, and techniques of research on their actual effects are difficult to devise. It is understandable that not all of the needed information in this field is fully developed today. However, studies are extensive and the fund of dependable knowledge is growing.

One of the problems that is being widely studied to help agriculture survive a nuclear attack is the effect of radioactive fallout and what can be done about it. In approaching this problem, we can start with the nuclear explosion itself.

NUCLEAR EXPLOSION

A nuclear explosion is accompanied by four destructive phenomena: (1) Blast, (2) heat, (3) initial radiation, and (4) residual radiation. The first three are almost instantaneous at the moment of detonation, but the fourth (residual radiation) produces its effects later, longer, and over a wider area, as fallout.

Area of Destruction

The area of destruction resulting from the blast, heat, and initial radiation will vary with the size of the weapon, the height of the explosion, and to some extent the terrain and atmospheric conditions at the time of the explosion.

The size of the weapon is measured in terms of its total energy release compared with the energy released by TNT when it explodes. For example,

a 1-kiloton nuclear bomb produces the same amount of energy as the explosion of 1 kiloton (or 1,000 tons) of TNT. A 1-megaton bomb has the energy equivalent of 1 million tons (or 1,000 kilotons) of TNT. The earliest nuclear weapon released roughly the same quantity of energy as 20,000 tons (or 20 kilotons) of TNT. The energy release of the large bombs developed since World War II is expressed in terms of megatons.

In general, the height of the explosion can be considered in one of four classifications: Air burst, surface burst, underwater burst, or underground burst. Obviously, whether the blast occurs high in the air, at or near the surface of the ground or water, underground, or underwater affects the area of damage.

Such elements of the terrain as mountains and hills also affect the blast and fire damage area. For example, a surface explosion surrounded by high hills or mountains might damage a more limited area than one on a broad flat plain. Wind direction or velocity and rain also influence the extent of fire damage.

The blast and heat damage resulting from a nuclear reactor accident would probably be confined to the power plant itself. A nuclear reactor is a device for the controlled release of nuclear energy for power or for research. The reactors are enclosed in tight containers and operated under stringent safety restrictions. Accidents would possibly allow radioactive gases to escape and contaminate the surrounding area as fallout, discussed in the next paragraph. Such an accident occurred in a reactor at Windscale in England in 1957.

Fallout Formation

When a nuclear explosion occurs close to the ground, particles of earth and debris--amounting altogether to thousands of tons of material and radioactive portions of the bomb--are taken up into the familiar fireball and rise in the mushroom cloud. Maximum temperature of the fireball approaches that of the center of the sun--millions of degrees Fahrenheit. In this heat, the particles of material are converted to gases. As these condense and solidify during cooling, they entrap radioisotopes formed from the bomb. Other particles do not fuse, but collect radioisotopes on their surfaces. All of these particles thus become sources of radioactivity.

According to estimates, about one-half of the material from a surface atomic explosion will return to the earth's surface as fallout within the general vicinity of the blast area in about 12 hours. The remainder may go high into the atmosphere--some may go even above the troposphere into the stratosphere--and gradually descend over a period of days or years anywhere in the world. The size of the fallout particles, together with the wind, rain, and other atmospheric conditions, will determine largely when and where they will fall to the earth's surface. (See figure 1.) The fallout is a source of radiation that can be hazardous to life in an area.

Area of Severe Fallout

In very general terms the region of severe local fallout contamination can be described as an elongated area extending downwind from the point

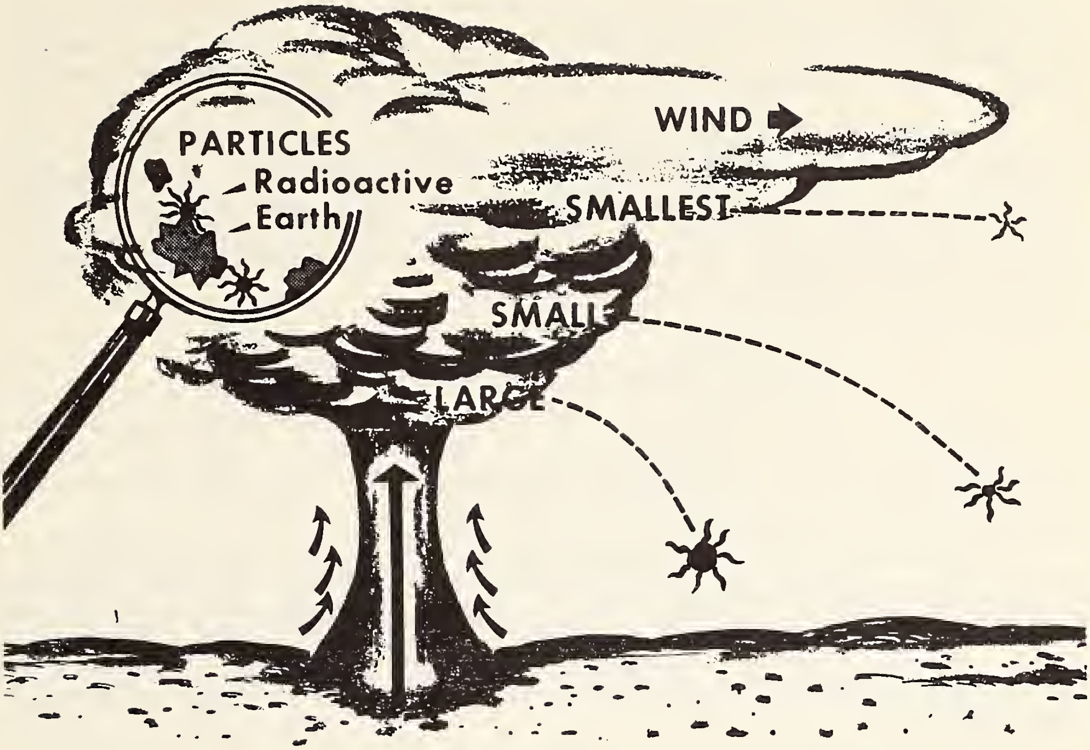

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Figure 1.--In a nuclear explosion thousands of tons of material are taken up into the fireball. As the fireball cools, radioactive particles formed from the bomb are fused with particles of dirt and debris to form radioactive fallout. Where it falls to earth depends in part upon the size of the particles, wind direction and velocity.

of burst. It is impossible to make an accurate estimate in advance of the size or shape of this area because so many variables are involved. However, as a point of general reference, the area of severe local fallout after a megaton surface explosion might be 20 miles upwind and about 200 miles downwind. The pattern may be irregular in outline and contamination within the area is usually not uniform. There may be local areas of extreme danger, others with very little contamination, and all gradations in between. These variations result from differences in local topography, rain, and other local atmospheric conditions.

It takes time for fallout to drop from the atomic cloud, even close to the burst. The earliest arrival time outside the totally devastated area might be nearly 30 minutes after detonation. Some areas within the elongated pattern of severe contamination might not get the fallout for as long as 24 hours after the explosion. It could continue to fall for a matter of hours.

RESIDUAL RADIATION AND FALLOUT

About 90 percent of the energy of a nuclear explosion is released through the blast, heat, and initial radiation. The remaining 10 percent of the bomb's energy is expelled as residual radiation in fallout. Arbitrarily, residual radiation can be said to begin about 1 minute after the explosion and continue for years.

Radiation is emitted by radioisotopes (fission products) produced by the explosion of the bomb. It can pass into and through matter. Radiation can change, damage, or destroy living cells through ionization (the production of electrically charged particles) of cell constituents.

Since fallout contains radioactive fission products, it emits nuclear radiation. The fission products have condensed in and on dust and soil particles. Therefore, fallout in many instances can be considered as radioactive dust. Physically it behaves like dust. Sometimes, in heavily contaminated areas, it is visible, as a fine white powder or tiny metallic flakes. But often fallout is not visible.

Radioactivity Not Transferred From Fallout

Radiation from fallout can damage living or inanimate matter, but it does not cause the irradiated matter to become radioactive itself. In considering the effect of fallout on agriculture, the radioactive contamination in the fallout itself is the principal concern.

Fallout as a source of radiation can be compared to a lantern as a source of light rays. When the lantern is in a room, it emits light rays that strike various objects. When the lantern is removed, the light rays are gone. In the same way, once the fallout is removed, the radiation is gone and the irradiated materials are not radioactive. However, the radiation damage to the living matter may persist or may not appear until later.

Gamma and Beta Radiation

Gamma rays and beta rays are the two most important types of radiation in fallout. Gamma rays are electromagnetic energy just as light, radio waves, and X-rays. They may be thought of as a kind of invisible light to which all things are to some extent transparent. The danger from gamma rays in fallout is greatest soon after it arrives in an area. The rays can travel long distances (many feet through air and several feet through water) and are difficult to shield against. Gamma rays can be reduced in intensity only by shielding with a sufficient quantity of material between the source of radiation and the subject, but they cannot be entirely stopped. In general the denser the material the less thickness is required for shielding against gamma rays.

Beta rays are particles similar to electrons. Beta rays can be easily stopped. Several layers of clothing can prevent penetration of beta rays. However, if a sufficient quantity of fallout gets on bare skin, beta rays will cause severe burns, and the effects are even more serious if fallout is eaten or inhaled by man or livestock. Some of the isotopes in fallout are concentrated in certain tissues of the body, where their beta rays may produce intense local damage. Some of these elements continue to emit beta rays for long periods of time--measured in years.

Decay of Radioactivity

About 200 different isotopes of nearly 40 elements have been identified among fission products created by nuclear explosions. The radioactivity of each isotope diminishes or "decays" at a specific rate, different for

each isotope. Usually the rate of decay is expressed in terms of the "half-life" of the isotope. Some isotopes lose half their radioactivity within seconds after the explosion. Others take days or months or years to lose half their radioactivity. For example, iodine 131 has a half-life of 8 days. Thus, iodine 131 has decayed to half its original activity in 8 days, half the remainder is gone in another 8 days, and so on. After 54 days, only 1 percent of the radioactivity will remain. Strontium 90 has a half-life of 28 years and 1 percent of the radioactivity of strontium will still remain after 180 years.

The total radiation hazard of newly formed or fresh fallout decreases rapidly at first because it contains many radioisotopes with short half-lives. The radiation hazard decreases more slowly after the shorter half-life elements have lost most of their radioactivity.

Other Sources of Radiation

Human beings and animals under normal conditions have always received radiation from many sources both inside and outside the body. One of the chief internal sources is the radioisotope potassium 40, which is a normal constituent of the element potassium as it exists in nature. An isotope of carbon, carbon 14, is also radioactive, and hence a source of internal radiation. Potassium 40, radioactive uranium, thorium, and radium in varying amounts, are present in soil and rocks. Finally, an important source of radiation to man is the cosmic rays from outer space.

During the average lifetime humans receive an estimated 10 to 12 rads[1] to the whole body from natural sources. The exposure to radiation from natural sources--generally called "background radiation"--has continued during the whole period of man's existence. In addition, a similar amount of radiation may be from localized exposures due to dental and medical X-rays, and similar treatments, and some is contributed even by the luminous dials of wrist watches and instruments.

External and Internal Radiation Hazards

Ionizing radiation from fallout creates two hazards to biological systems: (1) <u>External</u> radiation and (2) <u>Internal</u> radiation. Both are of concern to agriculture: First, as a potential hazard to farm people and their livestock, including poultry, and second, as a source of danger to the consumers of agricultural food products.

(1) <u>External</u> radiation is an acute problem that would be faced at the time the fresh fallout first arrives and drops to the surface of the land. The gamma radiation for a time soon after the arrival of early fallout is more hazardous than beta radiation since it is effective at greater distance from the source and is more difficult to shield against. As radiation intensity declines the beta radiation from particles in contact with tissue becomes relatively more hazardous. The effects of the radiation on man and animals can range from nondetectable damage through varying degrees

[1] A measure of radiation energy absorbed.

of "radiation sickness" to death. Also, radiation sickness can block the ability of normal body mechanisms to fight or overcome infections.

The human body is able to withstand continued exposure to small doses of radiation from natural sources without any obviously harmful consequences. The probable reason is that most of the cells damaged by radiation recover or may be replaced by tissue regeneration from unaffected neighboring cells. But if the rate of delivery of the radiation is rapid and the total dose received is large, recovery does not keep pace with the injury.

An amount of radiation will damage a living body according to the number and type of cells affected and by the type of tissue or organ affected. If the radiation damages the cell to the extent that its ability to function and reproduce itself is lost, and if enough cells are thus damaged so that it is difficult for surrounding tissues to repair or replace the damaged cells, then the injury is severe and lasting.

Therefore injury caused by a certain dose of radiation will depend upon the extent and part of the body that is exposed. For example, an acute exposure to 700 roentgens[2] applied to a small region may result in considerable biological damage to the irradiated area, but the overall health of the individual or animal may be apparently unaffected. If the entire body is exposed to 700 roentgens, death will probably result. Table 1 shows the expected percentage of radiation sickness and subsequent deaths in humans within 30 days or so for various acute radiation doses over the whole body.

(2) Internal radiation is the serious and long-lasting problem created by the consumption of contaminated food and water. It is caused chiefly by the isotopes that produce beta rays which are capable of traveling only short distances in the body. Once inside the body, they continue to damage the cells with which they come in contact. Most food commodities, both plant and animal, can be a source of internal radiation for consumers. Much study is being given to this phase of radiation hazard.

Table 1.--Expected Effects of Acute Whole-body Radiation Doses[1]

Acute Dose (Roentgens)	Effect
0-25	No obvious injury.
25-50	Possible blood changes but no serious injury.
50-100	Blood-cell changes, some injury, no disability.
100-200	Injury, possible disability.
200-400	Injury and disability certain; death possible.
450	Fatal to 50 percent; LD 50/30.[2]
600 or more	Fatal.

[1] From "Civil Defense Information for Food and Drug Officials," prepared by the Food and Drug Administration, U. S. Department of Health, Education and Welfare, December 1956.
[2] LD 50/30 - The quantity of radiation in roentgens that kills 50 percent of the test animals within 30 days after exposure.

[2] A quantity of radiation; 1 roentgen absorbed in tissue gives a dose of approximately 1 rad.

Research has developed information on protection against both external and internal radiation hazards of fallout. The remainder of this report deals with methods of protection for agriculture, farm families, and consumers of agricultural products.

MEASUREMENT OF FALLOUT RADIATION

Some measurements of radiation intensity are necessary in order to determine what protective measures should be taken. It is impossible to predict accurately the intensity of radiation that will be in any given location at any given time after the blast. In an emergency advance estimates based on known principles would be given and would be of value in preventing widespread sickness and death, but they must of necessity be of a general nature.

The intensity of total radiation from fallout at any given time is expressed in terms of a unit of measurement called a "roentgen." It is an accepted unit for measuring radiation in air, just as a calorie for heat or a kilowatt hour for electricity. The roentgen is used in two different circumstances: (1) Total accumulated radiation is expressed merely as so many roentgens. (2) The rate at which radiation is given off by fallout is expressed as roentgens per unit of time (per hour, minute, or second.)

The human senses do not detect ionizing radiation. Special instruments have been developed for the detection and measurement of various nuclear radiation.

These devices can be divided into rate meters and dosimeters:

1. Rate meters are used to measure radiation rates in an area. They are basically reconnaisance instruments to locate regions of high radiation intensity. For example, they would be used to determine the size and shape of the area of most intense radiation surrounding the blast area. They might be used in three ways:

(a) For fixed station monitors to give remote measurements (measurements that could be read from a distance without exposure to monitoring personnel.)

(b) For aerial surveys to enable officials to estimate general radiation levels over a wide area.

(c) For on-the-spot measurements of a given area.

Civil defense officials have adopted monitoring instruments or rate meters to be used for survey purposes in the event of emergency operations. Examples of those having the widest application are:

(a) The Geiger counter (CD V-700), the most familiar of these devices, is a highly sensitive instrument and is suitable for monitoring food, water, and personnel. It has a measurement range from zero to 50 milliroentgens per hour. (A milliroentgen is one-thousandth of a roentgen.) Such a short range of measurement would be of little use in an area with significant contamination since a relatively low level of radioactivity would drive the indicator needle off the scale. (See figure 2.)

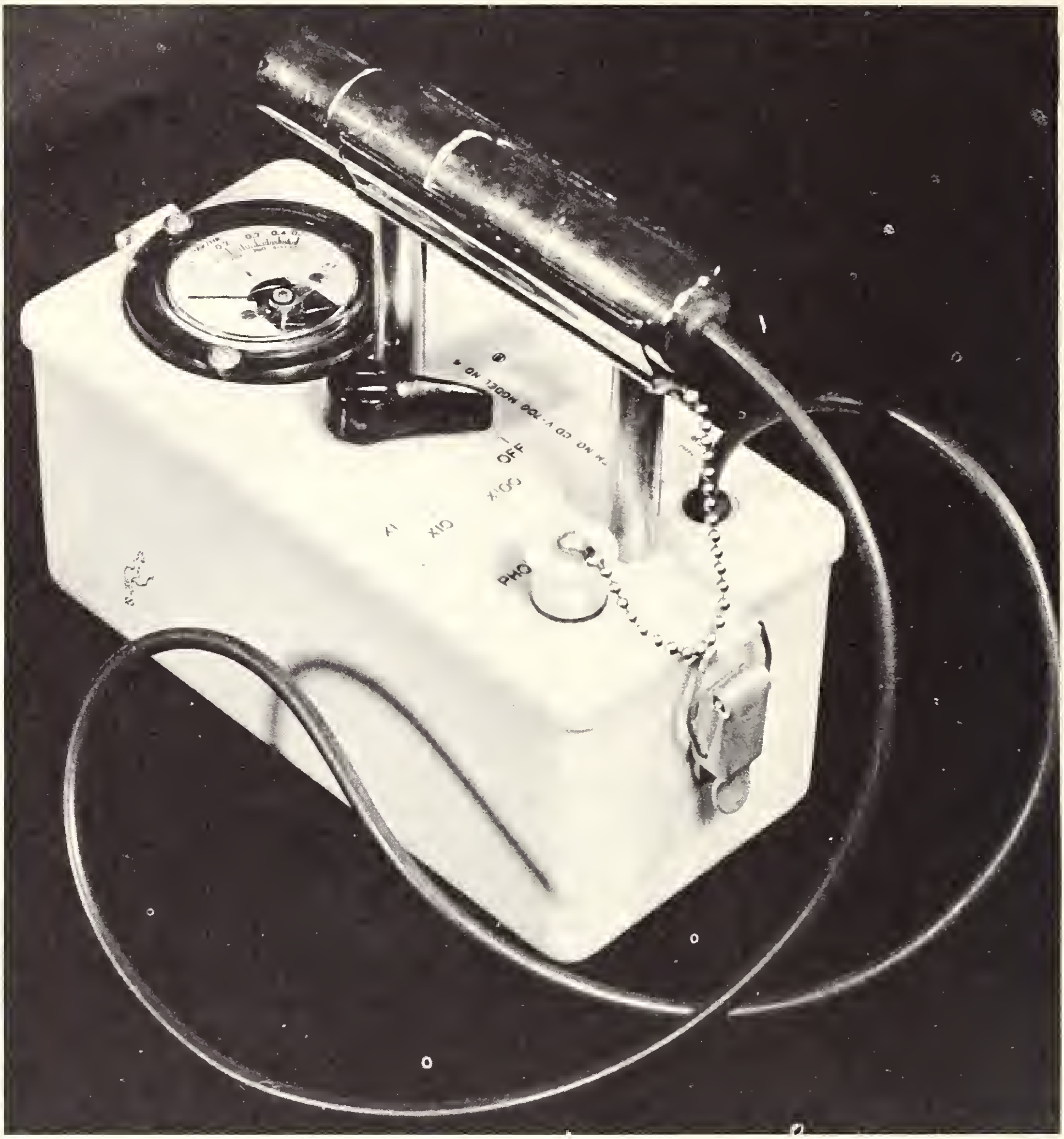

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Figure 2.--A Geiger counter is a monitoring device used to detect and measure radioactivity. Its range of measurement is very small, but in time of emergency it would be useful for monitoring food, water, and personnel.

(b) A medium range gamma survey meter (CD V-710) would be most widely useful for general radiological monitoring following attack. The measurement range is from zero to 50 roentgens per hour. The instrument is designed for ground or aerial survey where the radiation levels would be expected to change relatively slowly. (See figure 3.)

(c) A high-range beta-gamma survey meter (CD V-720) would be required in areas where contamination levels are extremely high and for making high level beta radiation measurements. This instrument has a measurement range from zero to 500 roentgens per hour.

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Figure 3.--A medium range gamma survey meter (above) would be generally used to determine the intensity of radioactivity at ground level following an attack.

2. Dosimeters are used to measure accumulated dose of radioactivity in an area or the accumulated exposure of people and livestock. (See figure 4.)

Civil defense has adopted self-indicating dosimeters for measuring accumulated radioactivity or radiation exposure of people. Two examples are:

(a) CD V-730 has a measurement range from zero to 20 roentgens.

(b) CD V-740 has a measurement range from zero to 100 roentgens.

Other dosimeters that are not self-indicating and require special training for reading have been developed for use of monitoring personnel. These are made up in the form of badges using chemicals, and photographic and electrostatic principles.

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Figure 4.--A dosimeter measures the accumulated dosage of radioactivity.

As part of the Nation's preparedness program, an adequate detecting device of some type is to be made available in each county in the hands of people trained to use it. In the event of a nuclear attack, States and local civil defense organizations would be responsible for keeping a regular check for radiation. As information on intensity and location of radiation becomes available, it will be broadcast on Conelrad radio stations at 640 and 1240 kilocycles.

PROTECTION AGAINST EXTERNAL RADIATION FROM FALLOUT

Radioactive fallout would have serious effects upon agriculture in the event of attack with nuclear weapons, but there are practical methods of protection. The three basic elements of protection against external radiation from fallout are: Distance, time, and shielding (shelter).

Effect of Distance

Distance is a natural protection against fallout radiation from external sources. As would be expected, the radiation exposure is less the farther away you are from the source of radiation. Thus, fallout on a roof 20 feet over your head will give less radiation exposure than the same amount of fallout on the same roof five feet over your head. This is true because the radiation is reduced in intensity as it moves away from the point of origin. (See figure 5.)

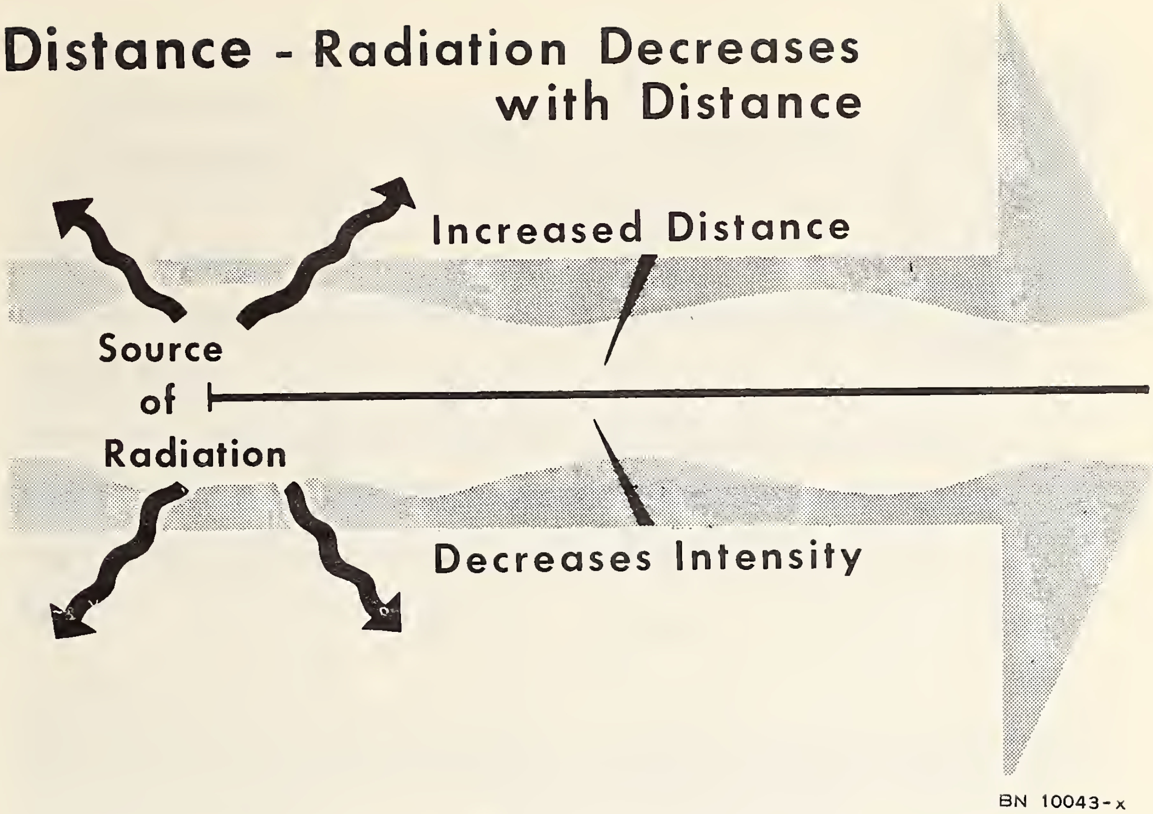

Figure 5.--Distance provides a natural protection against radiation. The farther away you are from the source of radiation, the less exposure you would receive.

Effect of Time

The lapse of time after a nuclear explosion is also a natural protection against the external radiation hazard from fallout because of the decay factor of radioactivity. The longer it takes the fallout to reach an area the more time allowed for radiation intensity to decrease due to decay.

In order to estimate the rate of decrease in total radioactivity, an approximate rule may be used. According to this rule, for every sevenfold increase in time following an explosion the resulting radiation decreases tenfold. For example: Suppose the radiation dose rate in an area is 1,000 roentgens per hour (1,000r/hr) at 1 hour after the explosion. If no more fallout occurs, seven hours after the explosion the dose rate would be 100r/hr (a tenfold decrease from 1,000.) In 49 hours (about 2 days) the rate will be down to 10r/hr. In 343 hours (about 2 weeks) the rate will be down to 1 roentgen per hour. It would take approximately 14 weeks for the radiation dose rate to be reduced to 1/10r/hr. (See figure 6.)

In order to evaluate these dose rates, we may consider the fact that "maximum permissible exposure" recommended for adults working in industries that expose them to radiation is 0.1 roentgen per week. Evidence from actual experience and research with animals indicates that a single acute exposure of the whole body of more than 10 roentgens would not normally result in obvious damage to the biological system. No maximum permissible exposures have been recommended for domestic animals.

TIME (hr.)	DECAY	RADIATION INTENSITY
1	—	1,000 r/hr.
7	1/10	100 r/hr.
7X7 = 49 (2 days)	1/100	10 r/hr.
7X7X7 = 343 (2 wks)	1/1,000	1 r/hr.

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Figure 6.--Decay in radioactivity is related to time. For every sevenfold increase in time following a nuclear explosion, the intensity of the resulting radioactivity decreases. When radiation intensity is 1,000r/hr 1 hour after an explosion, at 7 hours after the explosion the intensity would be approximately 100r/hr, or one-tenth of the original radioactivity.

Effect of Shielding

Shelter

The most important protection against fallout that farm families can provide for themselves is shelter. In time of emergency it would not be practical to evacuate the population from most areas because of the lack of information about where bombs might explode, and possible sudden and unpredictable shifts in wind direction and velocity which would determine the pattern of the fallout. Therefore, farmers should be prepared to provide shelter for their families and livestock, as well as for their food, feed, and water. The interval between the explosion and arrival of fallout may provide the time to get the family and livestock under cover and to cover water supplies, food, feed, and other critical items. (A guide for adequate shelter reserve food supply is included as an appendix to this report.)

The most critical period of radiation hazard is during the first 48 hours after a nuclear explosion. In an area exposed to radiation intensity of 1,000 to 3,000 roentgens per hour during the first hour of this period, total loss of man and livestock without shelter must be assumed. If man and animals can stay within a good farm building for the first 2 or 3 days, deaths from radiation can be reduced. The more effective the shelter and the longer it can be maintained, the greater the reduction in death rate and other effects of radiation.

Radiation Attenuation

Gamma rays are partially absorbed and reduced in intensity (attenuated) as they pass through any material. Therefore, shielding of any type gives some degree of protection. If enough shielding is provided between the individual and the source of radiation, such as fresh fallout, the exposure can be reduced to a negligible point.

The degree of protection provided by any material is measured in terms of "half-value layer." The term is used for much the same reason as the "half-life" decay rate of radioisotopes. Since absorption of gamma rays is theoretically not complete, the reference of measurement is that layer which will reduce the intensity to one-half. For example, if a person were out-of-doors without shelter in an area exposed to 400 roentgens, he would receive the full dosage. If he were shielded by a half-value layer of any material, he would receive only half the radiation, or 200 roentgens. Another half-value layer would cut the radiation in half again, or to 100 roentgens. Figure 7 illustrates this general standard of measuring the shielding of a half-value layer.

As a general rule, the degree of protection increases with the density of the shielding material. For example, less steel than concrete is required to provide a half-value layer--less concrete than earth--less earth than wood. While 0.7 inch of steel provides a half-value layer, it takes 8.8 inches of wood. A comparison of the most commonly available shielding materials is illustrated in figure 8.

These half-value layers are not exact under all conditions. However, they can serve as reasonable guides in the construction of shelters for the specific purpose of protecting against effects of radioactive fallout. If special shelters are not available at the time of a nuclear attack, farm families should take advantage of available normal indoor or, preferably, basement-type shelter.

Radiation is attenuated by normal shelter because of three facts: (1) The source of radiation--the fallout--will be largely outside, on the roof or on the ground and, therefore, not in immediate contact with man or animals; (2) radiation is partially absorbed by the roof and walls of an ordinary house and by the intervening air; and (3) radiation is diminished through the effect of distance. For example, experience indicates that a person on the first floor of an ordinary frame house in a fallout area receives about one-half the radiation dose received out-of-doors without any protection. If that person were in the basement of the frame house, his radiation dose would be reduced to about one-tenth the value outside the house. An underground shelter covered with a 3-foot layer of earth reduces the radiation to one-five-thousandth of the intensity on the outside. Tornado or storm cellars, cellars, and spring houses also provide good protection.

Table 2 indicates the reduction of gamma radiation inside various structures, giving the percentage of outside radiation received in each.

SHIELDING BY HALF-VALUE LAYERS

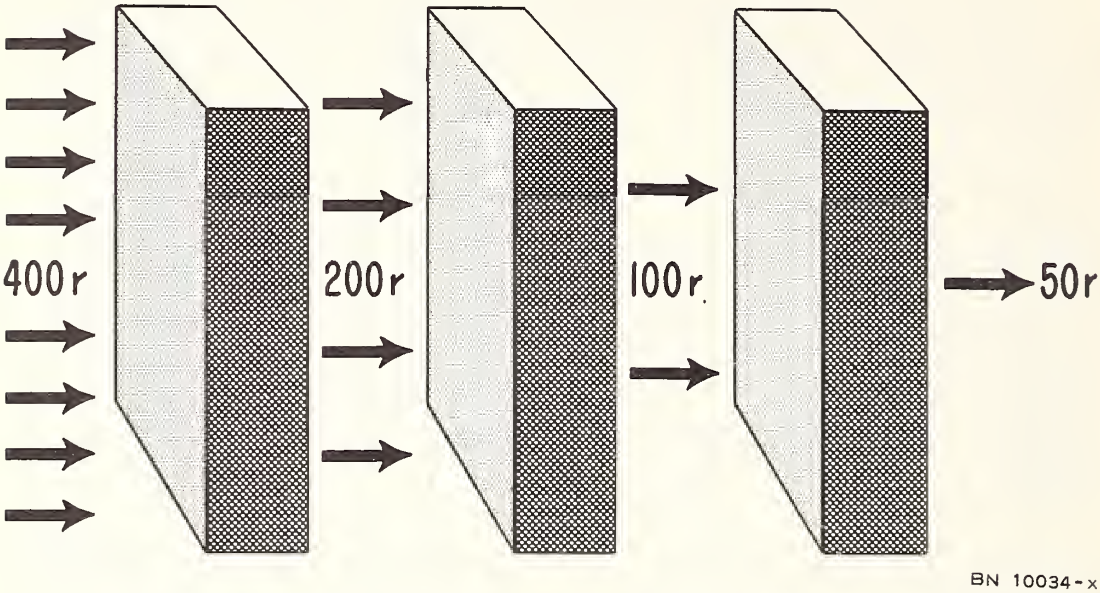

Figure 7.--A half value layer of shielding will absorb one-half the radiation exposure. The thickness shown here represents the half-value layer of earth.

HALF-VALUE LAYER THICKNESS

Provided by Commonly Available Shielding Materials

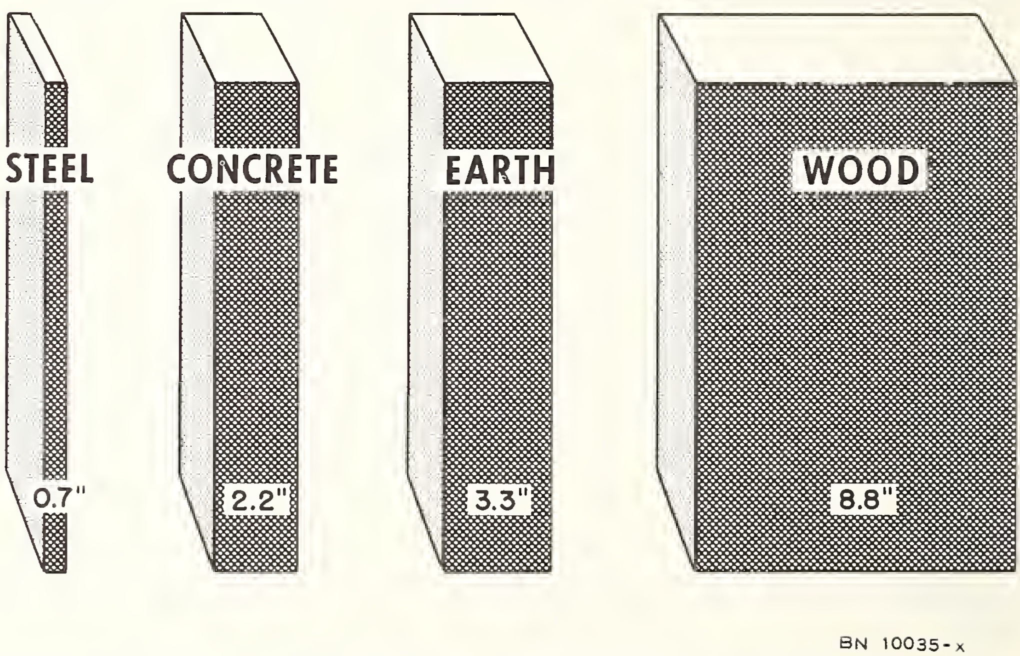

Figure 8.--The denser the shielding material the less required to provide a half-value layer.

Table 2.--Estimated Percentage of Outside Gamma Radiation Received in Various Structures[1]

Type of Structure	Approximate Outside Radiation Received
	Percent
Frame house:	
First floor	50
Basement	10
Barns:	
Shed-type	50
Basement-type	20
Multi-story, reinforced concrete:	
Lower floors away from windows	10
Basement surrounded with earth	3
Underground shelter covered with 3 feet of earth	0.02

[1] Adopted from "The Effects of Nuclear Weapons" prepared by United States Department of Defense and published by the United States Atomic Energy Commission, June 1957.

Maximum Work and Denial Times

After the first acute hazard of fallout has passed, farm families will be faced with the necessity of doing such farm chores as caring for livestock and making other necessary trips into the open. As long as supplies of food and water have been protected and are safe, appropriate schedules of work and shelter times can be devised that can save lives and reduce injury of men and animals. These controlled periods of exposure and shelter are called "maximum work times" and "denial times."

Where the gamma radiation level at H + 1 is 1,000r/hr or less, short out-of-door work periods can be scheduled after 1 day. In areas where the level is as high as 3,000r/hr at 1 hour after bomb burst, people can go into the open for short periods to perform necessary tasks after 1 week elapses.

These recommendations are not based on the assumption that measurements of radiation levels will be made in all areas at 1 hour after the explosion (H + 1). In many areas of high level radiation exposure, the fallout might not arrive for as long as 12 to 24 hours after the explosion. However, calculations can be made from later measurements to determine the level of radiation as of H + 1. This calculated radiation level enables one to use the tables in this report as guides for agricultural activities in contaminated areas.

Officials planning protection from fallout in case of nuclear attack have devised a maximum work timetable. It indicates as a general guide the number of hours a day that could be worked out-of-doors in various levels of gamma radiation without subjecting the person to more than 25r/day; 100r/week/ or 200r/total lifetime exposure. These work times are based on the assumption that at initial radiation levels up to 300r/hr, the remaining part of the day is spent in shelter equivalent to the basement of a frame house where no more than 10 percent of the outside radiation

is received. At 300r/hr it is assumed that the remaining part of the day is spent in underground shelter for the first week; after that the basement-type shelter will be sufficient. Work periods at 1,000 or more r/hr are based on the assumption that underground shelter is used between work periods, even after a year.

The recommended maximum work times are given in table 3. In using this table as a guide, it should be recognized that it assumes no change in the original distribution of fallout particles. In the passage of time, wind and rain could increase or decrease the concentration of fallout particles in many areas. In addition, some areas may be intentionally decontaminated. Actual measurements of radiation intensity should be used as accurate guides to work times.

Livestock Shelter

Livestock owners will generally find it impractical to remove animals from fallout areas. Therefore, facilities for the care of the animals in shelter and adequate supplies of uncontaminated feed and water for at least 2 weeks would be needed.

Animals should be kept within shelter at least during the first critical period of 24 to 48 hours. A good tight barn would reduce radiation dosage about one-half. The best shelter given by a structure normally in use for livestock is a 2-story basement type barn with a loft filled with hay. (See figure 9.) But any kind of shelter, even a shed without sides, gives some protection. Proper use of shelter for animals can substantially reduce the number of deaths and injuries from radiation.

Table 3.--Recommended Maximum Work Time Per Day for Areas Contaminated by Radioactive Fallout
(Total exposure would be not over 25r/day; 100r/week; or 200r/lifetime)

Entry time after bomb burst	Maximum work time when gamma radiation level 1 hour after bomb burst is--					
	10r/hr	30r/hr[1]	100r/hr[1]	300r/hr[2]	1,000r/hr[3]	3,000r/hr[3]
	Hours	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*
1 hour.....	No limit	1	--	--	--	--
2 hours ...	"	3	--	--	--	--
3 hours ...	"	5	0.4	--	--	--
7 hours ...	"	17	2	0.8	--	--
20 hours ...	"	No limit	13	3	--	--
1 day	"	"	16	4	1	--
1 week	"	"	No limit	7	2	0.8
1 month...	"	"	"	11	3	1.2
6 months .	"	"	"	16	5	1.8
1 year.....	"	"	"	19	6	2

[1] Based on basement-type shelter between work periods.
[2] Based on underground shelter between work periods for first week; after that basement type shelter will suffice.
[3] Based on underground shelter between work periods.

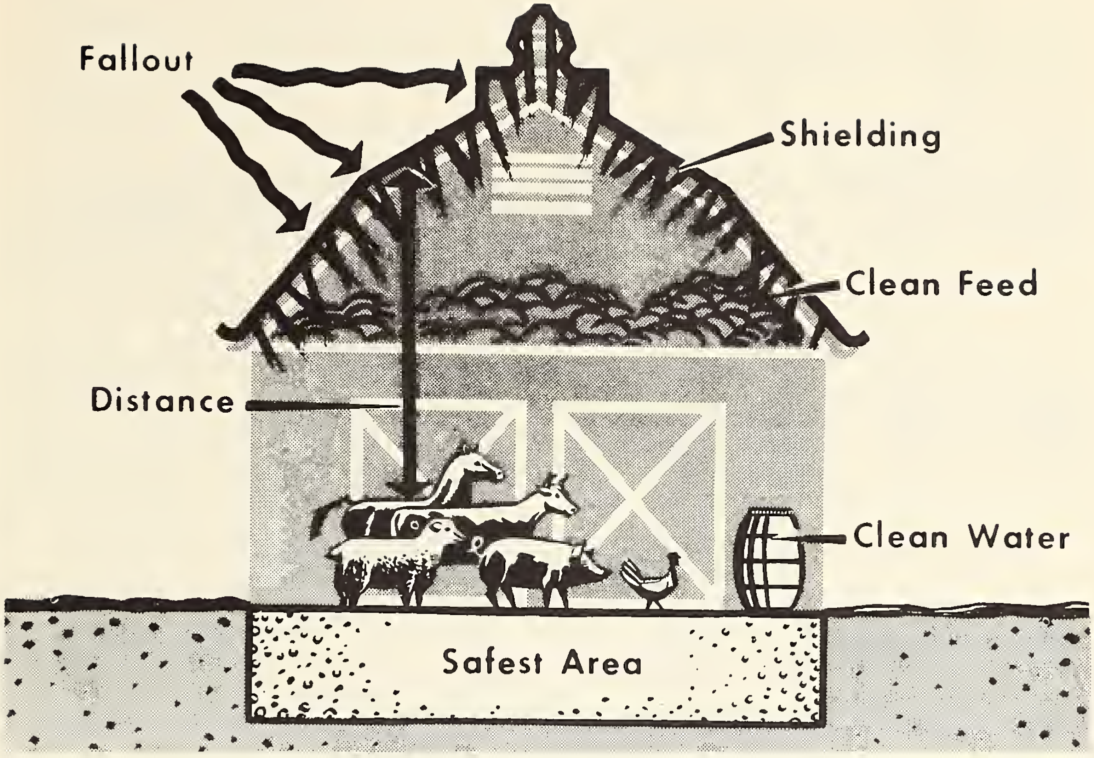

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Figure 9.--The best protection likely to be available for livestock against radioactive fallout is in the basement of a tight barn with a loft filled with hay.

Acute total body radiation exposures of animals to from 300 to 600 roentgens provides a midlethal dose--or the dose level which you could expect to kill 50 percent of the animals within 30 days. However, tolerance varies among species of animals as well as among animals within the same species. Table 4 indicates the percentage of mortality that might be expected among various species of sheltered and unsheltered animals exposed to different intensities of radiation. This information should be considered as a general guide of expected mortality based on current knowledge, and not as a forecast of exact mortality rates.

The value of shelter in preventing death and sickness is greatest in areas exposed to radiation levels about equal to the midlethal dose (300 to 600 roentgens). At low radiation intensities, there is little beneficial effect from shelter because no animals would become sick or die whether sheltered or exposed. At high radiation intensities, all animals would die under either condition.

Handling of Livestock

If animals have been directly exposed to fallout, they should be thoroughly washed off quickly if possible. After the first critical 24 to 48 hours or when out-of-door work periods can be scheduled, livestock can be given short periods of exercise in areas or yards that do not contain contaminated vegetation or water.

Table 4.--Mortality Rate of Livestock Affected by Three Levels of Radiation Intensity When Unsheltered and When Held in Two Types of Shelter[1]

Radiation exposure in number of roentgens per 24-hour period (outdoor dose)	Mortality rate by nature of shelter and kind of livestock		
	No shelter	Shed with tight wooden walls (Protection factor of 2)	Basement type barn with hay in loft (Protection factor of 5)
	Percent	*Percent*	*Percent*
		CATTLE	
600	50	0	0
1200	100	50	0
3000	100	100	50
		HOGS	
600	98	0	0
1200	100	98	0
3000	100	100	98
		SHEEP	
600	80	0	0
1200	100	80	0
3000	100	100	80
		POULTRY	
600	7	0	0
1200	100	7	0
3000	100	100	7

[1]The reduction of radiation by shelter is described as the "protection factor." For example, if the protection factor of any given structure is 2, then the intensity of outside radiation is reduced by one-half.

Even when animals have received sufficient radiation to cause sickness or death, there may be a short period (2 to 5 days) immediately after the critical dose when the animals will not show any injury. If the animals are needed for food, and if they can be slaughtered during this time, and if no other disease or abnormality would cause unwholesomeness, the muscle and muscle fat would be safe for use as food. Normally edible organs, such as the liver, would not be safe.

However, the butchering process would be complicated by the radiation level in the area during this early period and the additional exposure of the workers to fallout on the animals' hides and in the alimentary and respiratory organs. These organs (lungs, trachea, stomach, intestines,

esophagus, tongue, and lips) must be carefully removed to avoid contaminating usable parts. The hides, organs, and other parts containing fallout must be disposed of with care, preferably by burial at least 2 feet underground.

If any animal shows signs of sickness, it should not be slaughtered for food purposes until it is fully recovered and in good health. This may take several weeks or months. Sick animals may be treated according to the symptoms shown.

When it is no longer practical to keep animals off contaminated pastures, they should be confined to the smallest area on which they can be maintained. If the pasture is heavily contaminated, the grazing area should be even further limited and supplemental feeding with uncontaminated feed provided if possible.

PROTECTION AGAINST INTERNAL RADIATION FROM FALLOUT

The second phase of radiation hazard from fallout is internal radiation or exposure to the isotopes that enter the bodies of animals and human beings. These radioactive elements generally enter in food and water. However, during the first few days of fallout and during dusty periods later on, a significant amount might be breathed into the lungs. During these periods, humans should wear respirators or dust masks.

At first, the principal source of internal radiation is from externally contaminated edible plants when fresh fallout drops on the affected area. For livestock this would include primarily forage grasses and legumes. For man it would include fruits, vegetables, and milk--particularly for children. As time passes, and the contaminated food and feed have been discarded, the principal source of internal radiation for man and animals is indirect--from the contamination in the soil which is absorbed through plant roots into food and feed crops. (See figure 10.) When meat and dairy animals eat contaminated feed, the radioactive elements are absorbed into their bodies. Thus, man's food supply of both plant and animal products can become contaminated with radioactivity.

Radioisotopes Causing Internal Radiation

Many of the radioactive isotopes created by nuclear explosions are of minor concern, in the long-term hazard of internal radiation, because of (1) the small amounts involved, (2) their extremely short half-life, or (3) the fact that they are not incorporated into the food chain[4] and hence do not affect man and animals.

Among the isotopes that are taken up in the food chain are the following: Barium 140, cerium 144, cesium 137, iodine 131, iodine 133, promethium 147, ruthenium 106, strontium 89, and strontium 90. Of these,

[4]The food chain is the normal movement of nutrients from the soil through plant tissue--which become feed for livestock--through animal tissue--which, in turn, become meat and milk for man--through the body of man in the function of human nutrition. The extent of movement is shorter, of course, in that portion of human nutrition derived directly from plants.

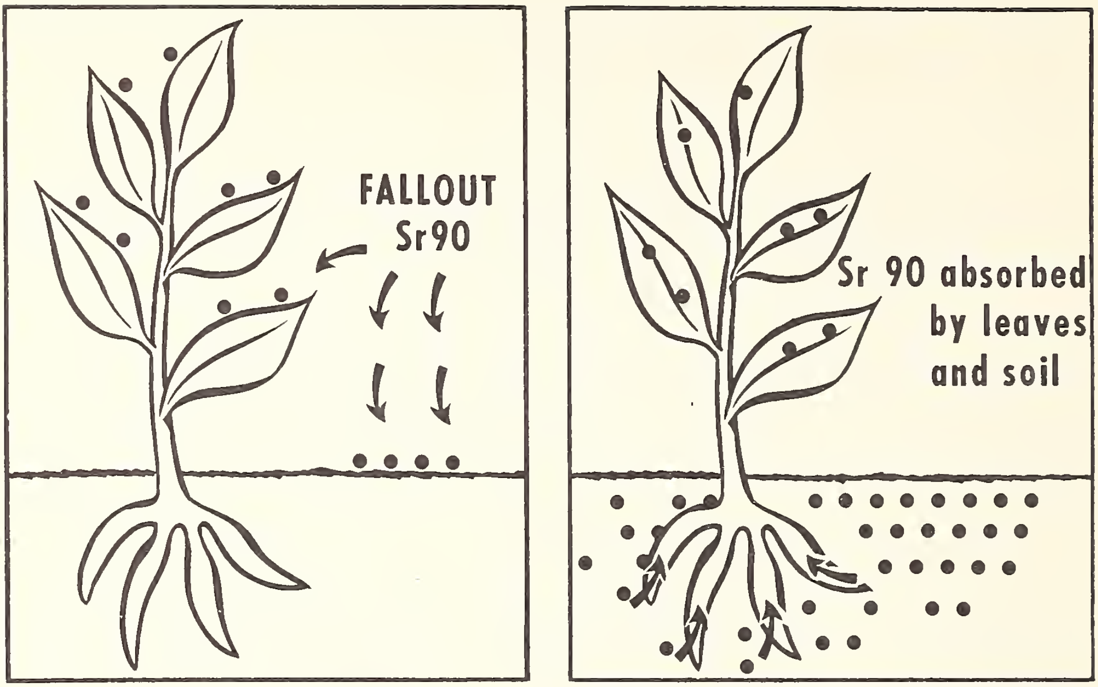

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Figure 10.--When fallout first arrives, it falls on the surface of the plant and soil. As time passes strontium 90 is absorbed into the plant leaves and into soil where it is available to be taken up by the plant roots along with nutrients.

the radioactive isotopes of most significance as internal radiation hazards are iodine 131, cesium 137, strontium 89, and strontium 90.

Radioactive iodine, because of its similarity to ordinary iodine, accumulates in the thyroid gland when it gets into the biological system. However, this isotope has a relatively short half-life of 8 days. There is general agreement among research scientists that iodine 131 will not be an important long-term fallout hazard, but it is the most hazardous element during the first 60 days.

Cesium 137 has a long half-life of 27 years and is chemically similar to the essential nutrient element potassium. When it is consumed and absorbed, it is found primarily in muscle tissue and can cause several types of cell damage, including genetic damage. But this radioisotope is not retained long in the body. It continually enters and leaves the system just as does potassium.

Strontium 90, however, with a half-life of 28 years, is of primary importance. Strontium 89 is similar except for a shorter half-life (53 days). They behave much like calcium in soils, plants, and animals. Nuclear explosions produce large amounts of radioactive strontium. It is taken up in biological systems, is secreted in milk, and collects in bones, where it remains for years. Radioactive isotopes of strontium deposited in the bone probably can produce serious consequences, including bone cancer and leukemia. But since radiostrontium is assimilated in the bones, it constitutes essentially no genetic hazard for its radiations do not reach the reproductive organs.

Protection of Food, Feed, and Water

The concern in protecting food, feed, and water is to prevent the consumption of contaminated materials which would subject man and animals to internal radiation hazards. However, the immediate problem is to shelter a sufficient quantity from the effects of fresh fallout to provide for survival during the early critical period.

The principle of protecting food, feed, and water from external fallout is simple: Prevent the fallout from becoming incorporated into the materials. They may be irradiated by the fallout, but if the radioactive particles do not come in actual contact with food, feed, and water--or if the fallout can be removed--the materials will not be radioactive and thus will be safe to eat or drink. Methods of prevention would be much the same as preventing dust from contaminating food or water if the air were heavily dust-laden. Fallout can also be removed in much the same way as dust--by washing, vacuum cleaning, and brushing. Precautions should be taken to avoid inhaling or ingesting the material while removing it.

Food

Meat and meat food products in home or commercial storage will be most effectively protected if canned. For uncanned products, a sealed covering of one of the commonly available plastic films, such as polyethylene, will provide adequate protection from contamination by fallout. Even fiberboard and similar tight containers which will exclude dust will be effective. Refrigeration facilities should be maintained as usual to control spoilage.

Vegetables and fruits harvested from fallout zones in the first month after attack will require decontamination before they can be used for food. First, the exposed parts must be thoroughly washed to remove the fallout particles. Then vegetables or fruits should be peeled, pared, or the outside otherwise removed in such a way that hands or utensils do not contaminate the parts to be eaten. It should be possible to decontaminate completely such crops as apples, headed lettuce, cabbage, or cauliflower by repeated parings, washing hands and utensils before each paring. It should be possible to wash and shell peas and beans or husk sweet corn to remove the contaminated parts. This type of decontamination could be applied to many human food items in the home immediately after harvest, preferably using well water, or other noncontaminated water.

Hazards from eating contaminated vegetables during the first 2 months following an attack would be greatest from strontium 89, iodine 131, and--to a somewhat lesser extent--strontium 90. As time passes, these hazardous elements of fallout will be incorporated more deeply into the inner parts of the plants and the proposed cleaning methods will be less effective. The amount of strontium 89 and 90 incorporated into plants will be only a few percent of the amount in the surface contamination. No estimate is now available concerning how much iodine will be incorporated in the plant. In any event, it would be advisable to use vegetables canned before the attack as much as possible.

Some food products that have fallout on or mixed in them can be used only after holding the products long enough to allow decay of the radio-

activity to a safe level. Obviously, many food products, including most meat which is not canned, could not be stored for the necessary time. Fallout on unpackaged meat presents a salvage problem since it is extremely difficult to remove the outer surface without carrying contamination onto other parts of the meat. Washing is not an effective method of removing this type of contamination. Some contaminated meat products could be canned and then stored until the radioactivity had decayed sufficiently.

The use of standing crops such as grain, fruits, and vegetables subjected to fallout will depend to some extent upon the stage of growth--that is, whether they can be allowed to stand until radioactivity has decayed enough to make it relatively safe to get to them for harvest. If fallout is heavy, ripe fruits may be lost because of the personal hazard in harvesting them. Fruits that do not have to be picked immediately and that can be decontaminated by washing and peeling before eating can probably be saved. Orchard trees should be maintained as usual and the fruits monitored for radioactivity.

Feed and Water

In protecting feed and water, the simplest method is to place a cover over them to prevent fallout from coming in direct contact with the materials.

Grain stored in a permanent bin or ensilage in a covered silo are provided with adequate protection against fallout and the contents can be safely used as soon as the farmer is able to get into the area to use them. The haystack in an open field can be protected with a covering such as a tarpaulin. The fallout will lodge on the tarpaulin, but by carefully removing it, the radioactive fallout will be removed. The hay and the contents of the feed bin and silo would not be radioactive and could be used immediately as safe feed for livestock. Many materials such as uncovered haystacks and piles of farm produce may be safely used as food and feed if the contaminated outer portions are removed.

Water stored outside--such as stock water troughs--should be covered with any material that would normally keep out dust. Larger farm ponds and lakes would be difficult if not impossible to protect. The mere boiling of water contaminated with radioactive particles will not make it safe.

Water from covered sources, such as springs and wells, would be essentially free from contamination even in heavy fallout areas and could be used for man and animals with confidence. (See figure 11.)

Radioactive Iodine and Radioactive Strontium in Milk

The study of radioactivity in milk has been more widespread than other foods for several reasons. Milk provides a vital part of the Nation's diet, particularly for young children, invalids, and older people for whom substitutions in diet are difficult. Because of the normal system of production and distribution of milk in this country, it is one of the easiest foods to test at central points and, therefore, more testing of milk has been done. Milk is produced throughout the year in all sections of the country so that samples are always available.

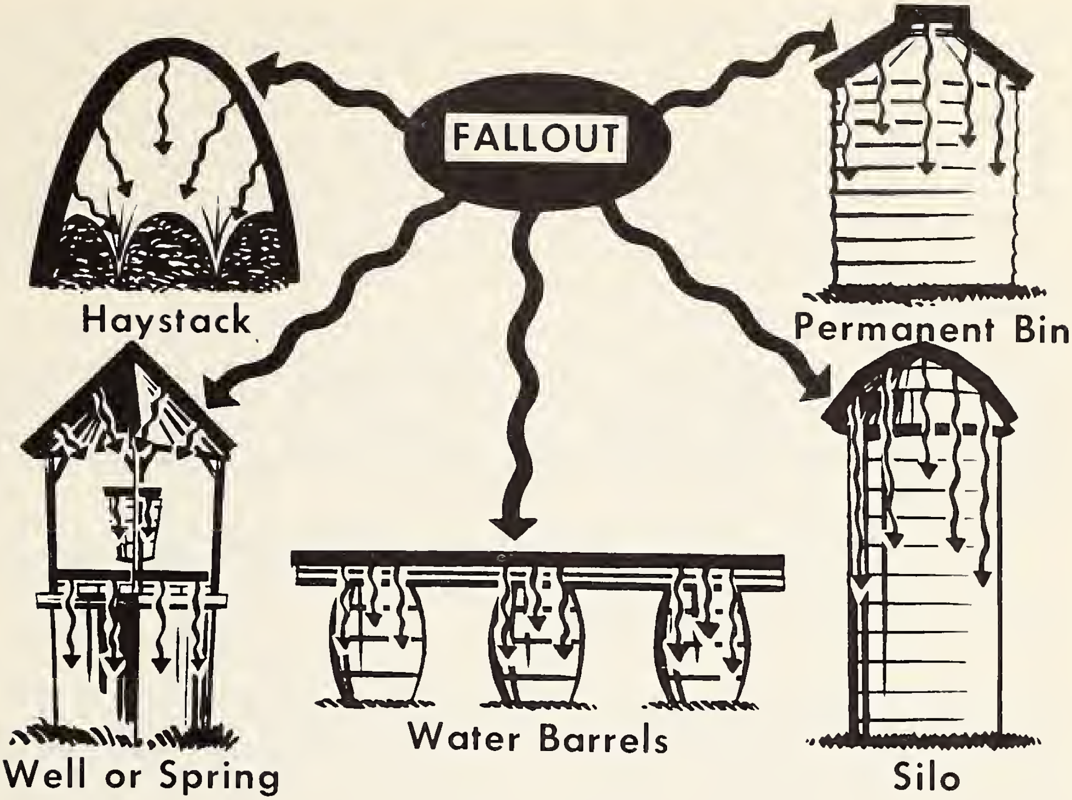

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Figure 11.--A tarpaulin on a haystack and other covering for feed and water prevent fallout from becoming mixed with the materials and thus prevent contamination. Even though the materials have been irradiated, when the fallout is removed from the covering the feed and water are not radioactive.

Several radioisotopes can be secreted in milk. Among them are iodine 131, strontium 89, strontium 90, barium 140, and cesium 137. The most important of these are iodine 131, strontium 89, and strontium 90. The effects of others are considered less important.

Radioactive Iodine

Some research workers have concluded that in the event of a nuclear attack, radioiodine would be the most critical factor in the contamination of milk during the first few weeks after an explosion. The hazard would be dissipated rapidly (in about 60 days) because of the decay factor, but the short time problem would be acute. Also, radioiodine would be one of the hazardous isotopes most commonly contained in contamination resulting from reactor accidents. The same general precautions should be taken to protect against the hazards of radioiodine in milk, whether it results from a nuclear bomb or a nuclear reactor accident.

A large fraction of the radioiodine consumed by human beings is deposited in the thyroid gland. Children are relatively much more sensitive to the effects of radiation on thyroid than are adults. Evidence indicates that a radiation dose of 200 rads to infants' thyroids can result in the incidence

of thyroid cancer in a few percent of exposed children. It has been calculated that an intake of 12.3 microcuries[5] of radioiodine would give a dose of 200 rads to the thyroid. On the other hand, it appears now that adults can tolerate 4,000 rads to the thyroid with no observable symptoms. The infant thyroid weighs about 1.5 grams, and the adult thyroid weighs about 20 grams. Therefore, a greater amount of radioiodine is required to damage the adult than the infant thyroid. Since milk is an essential food for infants and other young children, and the weight of milk consumed by them is high in relation to their body weights, the contamination of milk with radioiodine during the first 60 days after nuclear attack would be primarily a problem of thyroid injury to young children.

The hazard is created by dairy animals grazing on vegetation contaminated with radioiodine from fallout and thus producing contaminated milk. Based on current knowledge, U. S. Department of Agriculture scientists have developed suggestions aimed at reducing the hazards of radioiodine in milk in the event of nuclear attack:

Milk produced from pastures that received a radiation level of 10r/hr or higher 1 hour after a nuclear bomb explosion should not be used immediately for human consumption. For example, several days after a nuclear explosion, civil defense authorities measure the radiation level in a given county. From this measurement, the radiation level comparable to H + 1 can be determined. If this is as high as 10 roentgens per hour, then milk produced by cows grazing in that area should not be used by adults for 5 days or by children for 65 days after the explosion. Infants under 2 years old should not drink milk from such pastures until 80 days after the explosion, unless specific radioiodine measurements show the milk to be safe. Table 5 indicates the time before acceptance at other levels of radiation.

Table 5.--Periods of Time Before Milk Contaminated with Various Levels of Radioactivity Should be Accepted by Children and Adults[1]

Roentgens per hour at H + 1	Days before acceptance by:		
	Infants under 2 years	Children 2 - 16 years	Adults over 16 years
1	50	35	0
3	65	49	0
10	80	65	5
30	94	79	19
100	110	95	35

[1]Estimates based on radioiodine contamination and the rate of its radioactivity decay.

Stockpiles of storable milk or milk products for children are needed. Some areas, affected by fallout but not by the bomb blast, would not be producing fresh milk for 60 days if the above standards are met. Therefore, families with children should keep an ample supply of dry or canned milk on hand to help provide necessary nutrients during this period. This should be rotated into current use and the reserve replenished regularly. (See

[5]A curie is a measure of radioactivity equal to that of 1 gram of radium, and a microcurie is a millionth of a curie.

Appendix.) It would be feasible with medical supervision to supplement the diet with a strontium-free purified calcium compound in tablet or powdered form.

Adults and children who can safely forego the consumption of milk for several months should not drink milk during the critical period. During the first weeks after the explosion, adults and children who can get an adequate diet from other foods, should leave the restricted safe milk supply for infants and others for whom it is a mainstay in the diet.

Milk produced from existing vegetation in areas of higher radiation levels can be converted into storable dairy products or animal feed. In areas in which the radiation level at H + 1 was 10r/hr to 100r/hr, dairy cattle may have to continue to graze contaminated pastures. The milk production can be converted into such products as dried milk, cheese, butter, and ice cream. These products should be stored until the radioiodine has decayed to a safe level as indicated by table 5. The milk might also be fed to calves, pigs, or other livestock and the meat thus produced would be safe for human consumption.

Radioactive Strontium

After the first 60 days, the principal hazard of radioactive contamination in milk is strontium 90. Just as other radioactive isotopes of fallout, strontium 90 falls on the surface of plants and can be consumed with foods and forage. Some of it is washed into the soil, remaining indefinitely--for all practical purposes--in the top several inches. From here it is taken up by plants along with calcium. When the plants are eaten by dairy animals, the radiostrontium enters the bone and milk.

Fortunately, there is a protective mechanism termed the "discrimination factor." As the strontium and calcium move together through the food chain from the soil to the plant, through the body of the animal to the milk, and then through the body of man to its resting place in the bone, relatively more calcium than strontium is left. This is the natural discrimination between calcium and strontium.

About 70 to 80 percent of the calcium in the average diet in this country comes from milk and cheese. This calcium would carry only about 38 percent of the strontium associated with our food. The discrimination factor in the biological system of the cow affects the composition of milk, and only about 1 percent of the strontium in the feed is transferred to the milk. Plant foods--grains, vegetables, and fruits--furnish about 16 percent of the calcium in the diet but because they are consumed more directly, they furnish 60 percent of the total strontium. Meat and eggs contribute about 6 percent of the calcium and 2 percent of the strontium in the diet. (See figure 12.)

After the food has been eaten, the discrimination process within the human body serves to protect still further against the accumulation of strontium 90 in bones. The ratio of strontium to calcium retained in bone is only about one-fourth the ratio in the diet. If the ratio in the human diet is 16 units of strontium to 1 gram of calcium, then the ratio in the bone will be about 4 units per gram of calcium.

SOURCES OF CALCIUM AND STRONTIUM 90
From Food

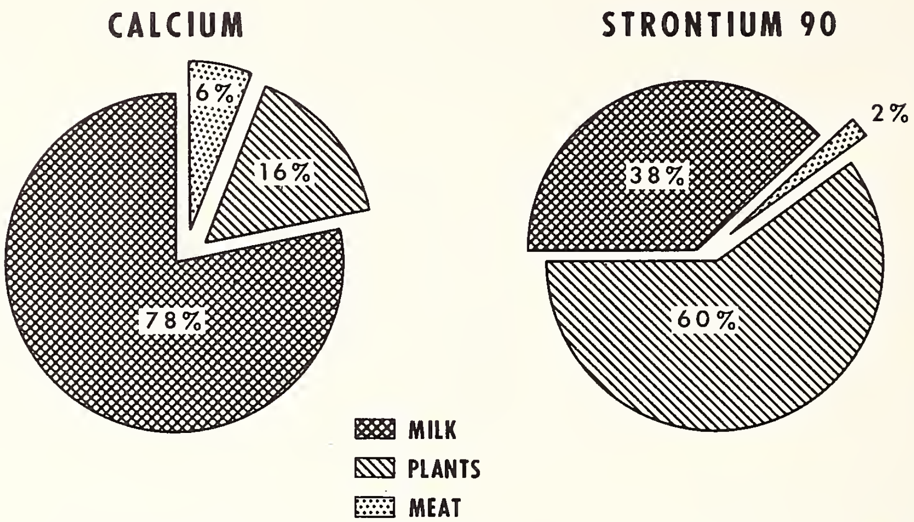

Figure 12.--Sources of the calcium and strontium 90 that are contained in human bones are principally milk, plants, and meat. The discrimination factor is demonstrated by the large percent of calcium derived from milk while the relatively small amount of strontium 90 is being accumulated.

Milk should continue to be the outstanding source of calcium in the diet because the calcium it supplies has had much of the strontium present in vegetation screened out by the biological system of the cow. Results of research on animals indicate that a body well nourished with respect to calcium does not retain as much strontium as a body that is deficient in calcium.

Croplands Contaminated by Fallout

A nuclear attack on this country could contaminate millions of acres of crop and range lands with radioactive fallout. This contamination presents a twofold problem: (1) The external exposure of agricultural workers who attempt to enter heavily contaminated areas--or to leave protective shelter in such areas--to carry out farm duties; and (2) the continued production of food without excessive internal radiation hazard to the population, because succeeding crops grown on this soil would take up the contamination.

The first hazard of external exposure can be at least partially combated by observing maximum work and the resulting denial times for outdoor activity as suggested in table 3. In combating the second hazard, research workers are conducting studies on methods of using contaminated soil for agricultural purposes or for decontaminating it.

Use of Contaminated Land

One of the first decisions to be made by agricultural leaders is how to use land contaminated with fallout in order to continue to produce a survival

diet for the Nation. Table 6 has been devised to serve as a guide for such decisions. Land contamination levels for each food group are based on the expected strontium 90 content of the foods. Land contamination levels for denial of the use of the land for the various food groups have been derived from scanty research information and may be raised or lowered as more information becomes available.

Table 6.--Land Contamination Levels (Gamma Intensity at H + 1) Above Which Production of Foods Should be Prohibited, by Calcium Level of the Soil

Product of land	Contamination level on land with		
	Low Ca (2,000 lbs/A)	Medium Ca (6,000 lbs/A)	High Ca (20,000 lbs/A)
	R/hr	*R/hr*	*R/hr*
All foods, if they all come from a contaminated area...	30	100	300
All foods other than dairy products, if they come from a contaminated area, and dairy products are free from contamination	45	150	450
Meat, eggs, and poultry, if all other foods are free from contamination	300	1,000	3,000

With the present average diet, Americans are expected to derive about one-third of their strontium 90 from dairy products, one-twentieth from meat and eggs, and the remainder from plant products, including fruits, vegetables, and cereal products. (See figure 12 for more precise estimates.) If uncontaminated milk and dairy products are used, other foods from plant and animal sources can be accepted from land with 50 percent more contamination (as indicated in table 6) without exceeding the permissible limit for strontium 90 in the total diet. If dairy products and food from plant sources could be obtained free of contamination, meat, eggs, and poultry could be accepted from land with much higher levels of contamination.

Contamination of crops with strontium 90 depends markedly on the available calcium content of the soil. For simplification of the table, soils have been grouped as low, medium, or high in calcium content of the root zone, which is considered to be about 1 foot for most soils and crops. A sandy loam soil with pH of about 5 may contain 2,000 pounds or less of available calcium per acre. An average loam soil with pH of about 6 may contain 6,000 pounds of available calcium and would be considered medium. A silt loam or silty clay loam with pH of about 7 may contain 20,000 pounds or more of available calcium, and would be considered high. The available calcium contents of most agricultural soils of the country are well known from soil test data.

Denial levels for soil use are set on the assumption that the land is limed and fertilized for subsequent crop plantings according to the requirements of the soil for maximum production. The denials are suggested for an indefinite period unless modified by other measures. For example, decontamination of the soil by such methods as surface soil removal and deep plowing would also modify the availability of the land for agricultural production.

Contaminated soil may be diverted to other uses if the radiation level is too high for the original type of production. The diversion may mean changing the species of crop grown on the land. The quantity of strontium 90 absorbed could be reduced by growing crops with low concentrations of strontium and calcium in their edible tissues. However, since plants are a source of calcium, the calcium content of diets would be reduced. Unless alternative sources of dietary calcium were provided, cultivating low-calcium crops would have obvious limitations. Potatoes, which contain about 10 milligrams of calcium per 100 calories, are a particularly suitable crop in contrast to leafy vegetables, which may contain 100 to 1,000 milligrams of calcium per 100 calories. Sugar and oil crops would also be suitable low-calcium crops for substitution on land too heavily contaminated to produce other foods.

If the top several inches of the soil are contaminated with strontium 90, the land may be diverted to deep rooted plants because they draw their nutrients primarily from below the contaminated layer. For example, contaminated land could be taken out of shallow-rooted grasses or crops and used for producing deep-rooted crops such as alfalfa with less uptake of the radioactive material. (See figure 13.)

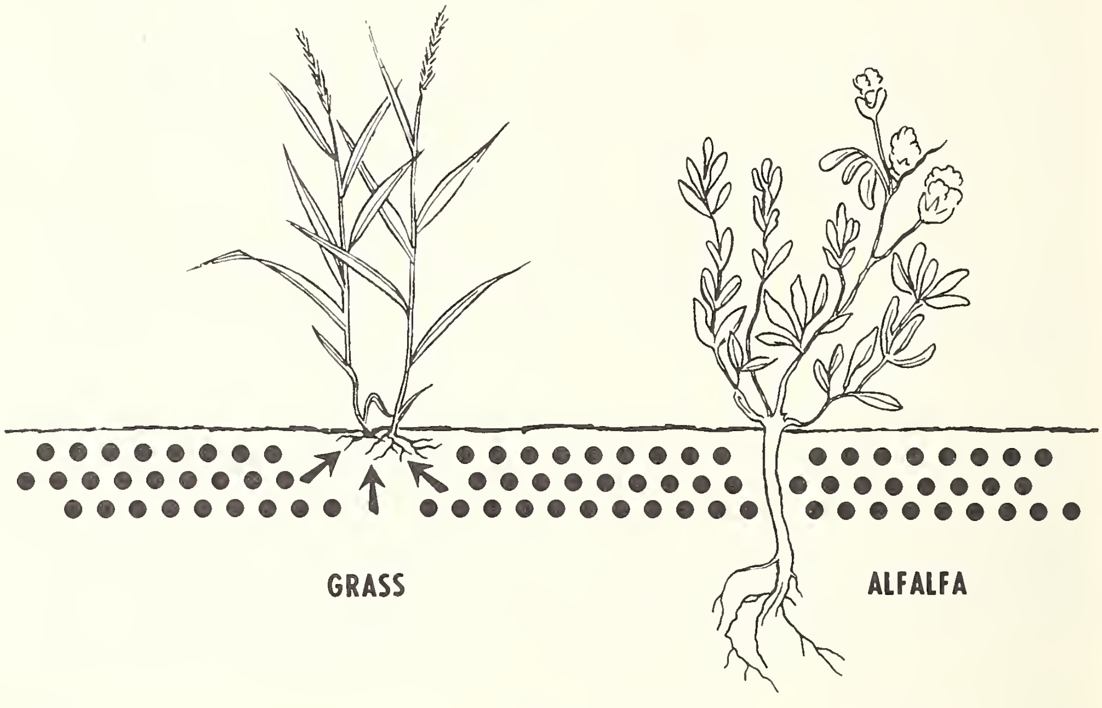

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Figure 13.--Root depth affects the uptake of strontium 90 because it stays principally in the top several inches of uncultivated land. There is little uptake in deep-rooted plants.

Land formerly used for dairying can be diverted to beef or other meat production. The strontium retained by animals grazing contaminated pastures goes mostly into the bones or milk and not into the meat. Consequently, the meat produced on contaminated land, within the limits set in table 6, could be carefully boned and used for food.

Byproducts of crops produced on contaminated land, such as beet pulp, cotton seed, linseed, and soybean oil meals, should be used as animal feeds only in accordance with the levels of contamination set in table 6. Milk produced on contaminated pastures could be used as feed for meat production.

Another diversion might be to take the land out of food consumption and use it for cotton fiber, flax, castorbeans, timber, or other nonfood production. If the land is very heavily contaminated, it might have to be taken out of agricultural production for an indefinite period.

Erosion of soil and runoff of water move deposited fallout and radioisotopes down slopes to lower lying areas where they may accumulate in concentrations higher than those in the upland soil. Areas subject to accumulation should be monitored frequently, especially if used for crop production.

Croplands Contaminated by Irrigation Water

Irrigation waters will not add much strontium 90 to agricultural land compared with direct fallout on the cultivated soil or on crops themselves. Strontium 90 and other fallout isotopes are considerably diluted in surface waters of any appreciable depth. Most of the radioactive contaminants, including strontium 90, are readily adsorbed by the soil of the banks and bottoms of lakes and streams. They are subsequently adsorbed further by canal linings and ditch banks. Any strontium remaining in the water is subject to rapid adsorption at the surface of the cultivated soil with which the water first comes into contact, and thereby is added to the surface accumulation originating from direct fallout.

Direct contamination of crops by sprinkler irrigation with contaminated water pumped from lakes, streams, or ponds would be a greater hazard, particularly to leafy vegetables. Irrigation water used for such purposes should be as free from radioactive contamination as drinking water.

Reclaiming Contaminated Soil

Decontamination of soils is necessary only for the removal of strontium 90. Other biologically significant fission products either are taken up from soils by plants in much smaller amounts or have such short lives that decontamination is not necessary. In zones of heavy fallout, the most stringent decontamination measures available will be necessary in order to reduce the strontium 90 content of the soil to a level acceptable for production of vegetables and milk. (These products absorb a greater percentage of the available strontium 90 than do others.) For production of other crops, or in zones of lighter fallout, it may be sufficient to use less effective practices which reduce the uptake of strontium 90 to a lesser degree. Obviously, heavily contaminated lands (over 1,000r/hr at H + 1) should be placed in cultivation only when their use is absolutely necessary.

Decontamination by Removal of Ground Cover

Decontamination by the removal of ground cover is effective when the existing cover is thick enough. The cover provided by sod or by a mulch consisting of 2 tons of oat straw per acre is practically complete. Figure 14 illustrates the relative effectiveness of fallout removal provided by removing mulch, sod, and standing crops. More than ninety percent of the fallout on sod or mulch may be removed by removing the sod or raking off the straw. Standing crops usually provide less complete ground cover, especially when young, and their harvest may remove only a small fraction of the fallout.

Contaminated crops could be disposed of by harvesting and baling to reduce their bulk. The bales must be stored where they will not contaminate other foods. The workers should wear respirators to avoid breathing the dust created by these operations. Clothing should be kept as clean as possible. Thorough washing of the hands and face is necessary before eating.

Decontamination by Removal of Surface Soil

The removal of surface soil is one of the most effective methods of decontamination, but it would be expensive and--with the procedures developed at this time--not suitable for large acreages. It might be useful if small clean areas are needed to produce food for survival.

The effectiveness of decontaminating surface soil by scraping ranges from partially successful for rough land to highly successful for smooth

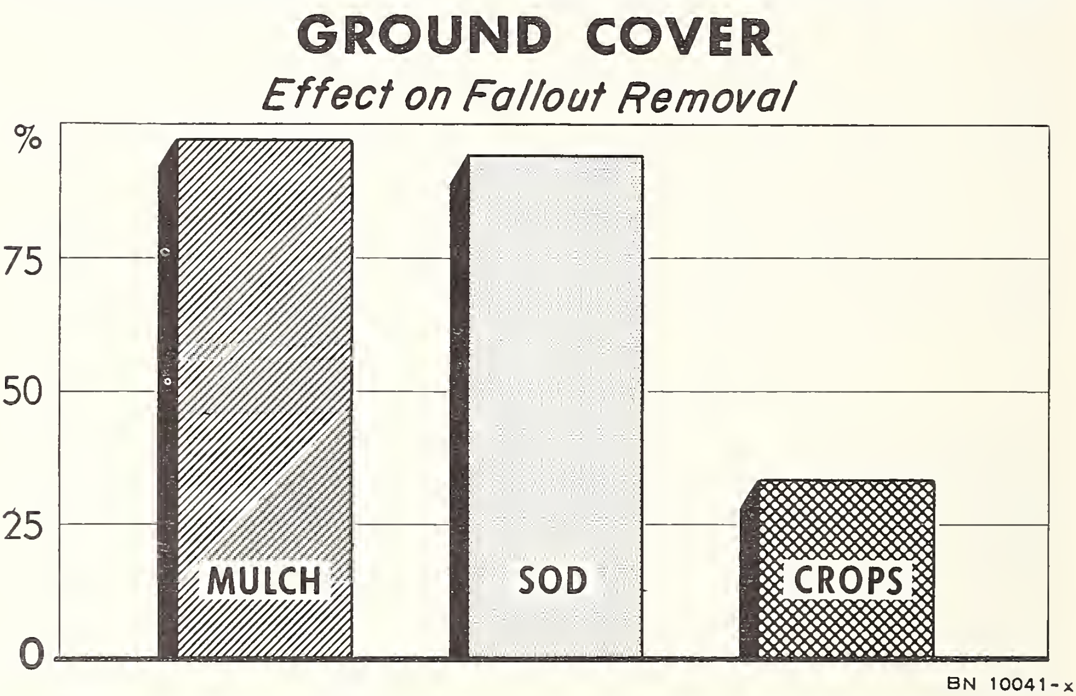

Figure 14.--If the ground is covered with mulch, sod, or a standing crop when fallout arrives, some of the contamination can be removed by removing the ground cover. The mulch represents two tons of straw per acre. Removing standing crops is not effective enough to be considered a practical means of fallout removal.

land. Rough, freshly plowed surfaces are difficult to decontaminate. Scraping off 2 inches of soil with a road grader may remove over 99 percent of the fallout from smooth soil, and only 60 percent from rough soil. Rough soil surfaces may be decontaminated more completely by scraping off more soil. Just as in harvesting, precautions against breathing dust and for cleanliness will be necessary.

Figure 15 illustrates this difference between rough and smooth soils, showing the most effective removal from the smooth seedbed as compared to the slightly rougher disk-harrowed soil and rough-plowed ground.

The safe disposal of contaminated surface soil after removal is a serious problem. For the large volumes of soil involved, the only practical places for disposal appear to be pits in the center of small fields or regularly spaced ditches across fields. The pits or ditches would have to be protected from erosion and should not be used for crop production.

Other Methods of Decontaminating Soil

Several additional methods of decontaminating soils do not appear to be practical on a field scale. Among these are leaching and cropping soils to remove strontium 90. Leaching would require extremely large amounts of water and calcium salts or acids. In addition to removing strontium 90, plant nutrients would be leached out of the root zone and would have to be replaced. Cropping, even with those crops known to take up large amounts of calcium and strontium, would require more than 40 successive crops to achieve 90 percent decontamination.

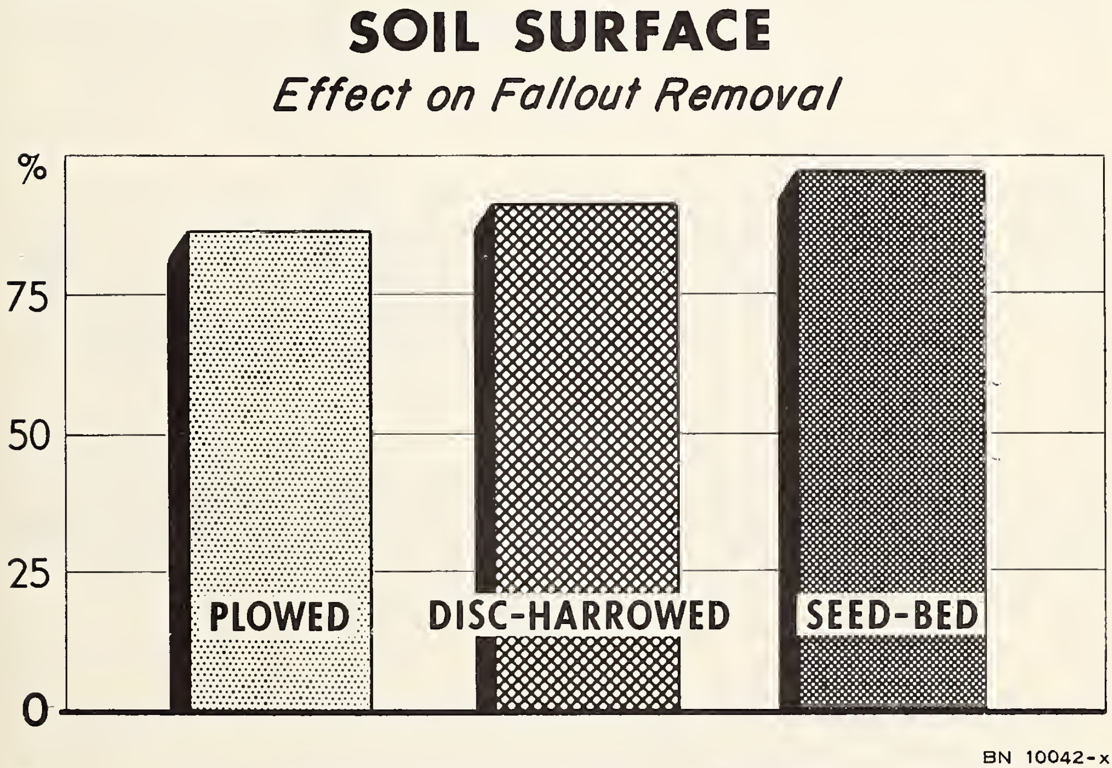

Figure 15.--Removing the top two inches of soil surface can be an effective method of soil decontamination. When the surface is smooth as in a seed bed the removal of fallout is more effective.

Reducing Strontium 90 Uptake with Soil Amendments

Addition of lime, gypsum, fertilizers, or organic matter in practical amounts usually reduces uptake of strontium 90 by less than half. Combinations of soil amendments and tillage practices may reduce uptake more than any single amendment would. The best use of soil amendments for maximum crop production is often the same as their best use for reducing strontium 90 uptake.

The plant's need for the calcium of lime or gypsum leads to the absorption of the similar element strontium. In soils low in exchangeable calcium, more strontium 90 will be taken up by the plant. By liming acid soils, more calcium is made available to the plant and less strontium 90 will be absorbed. This method is illustrated in Figure 16. It is useful on highly acid soils on which liming would be normally beneficial for other reasons. Gypsum would be most useful on soils containing large quantities of exchangeable sodium, which would normally need lime or gypsum regardless of the strontium 90 hazard. However, at best, the strontium uptake can be reduced by the application of lime to about one-half the uptake if the soil were not treated.

Potassium fertilization at the rate of several hundred pounds per acre can also reduce the uptake of strontium 90. However, the calcium uptake by the plants is also reduced by this practice. Crop residues and manure applied at the rate of 20 tons per acre have reduced the uptake of strontium 90 by one-third.

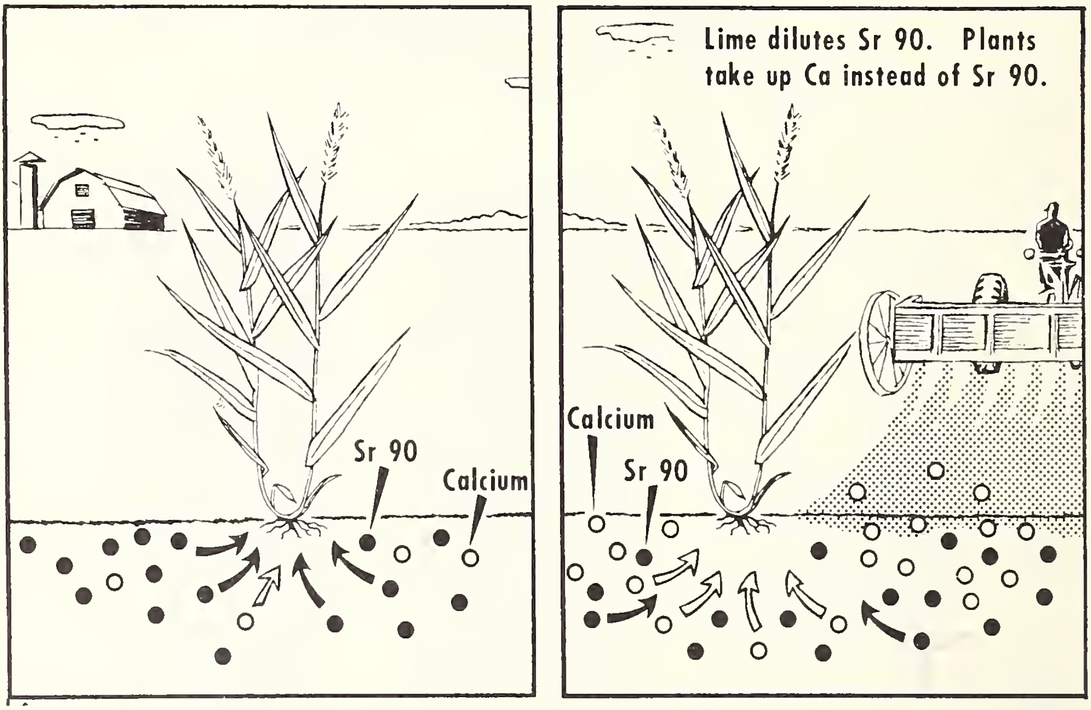

Figure 16.--Addition of lime to contaminated acid soil dilutes the strontium 90 present and favors the uptake of calcium instead of strontium 90 by plants.

Reclaiming Soil by Deep Plowing

Decontamination by deep plowing would be aimed at turning the contaminated surface soil under to a depth of 18 inches or more--or below the root zone of the plants that are to be grown. In shallow-rooted crops, such as grasses and many vegetables, deep plowing might reduce the uptake of strontium 90 by about one-half of that under normal cultivation. It will be most effective when the freshly exposed surface soil has a high supply of calcium either naturally or by addition of lime or gypsum. However, before the method is used, careful evaluation should be made of the situation in the area and of the alternatives. Once strontium 90 has been plowed under, future removal is extremely difficult. Also, the productivity of some soils may have been drastically reduced.

SUMMARY OF EFFECTS OF FALLOUT ON AGRICULTURE

An evaluation indicates that the total effect of radioactive fallout on American agriculture in case of nuclear attack would be serious. A series of nuclear explosions in populated areas would create hazards of severe radiation injury to farm people and their livestock. Radioactive contamination of food, feed, and water would increase the hazard. Residual contamination in the soil would continue the problem over a long period of time.

On the other hand, research is providing the basic knowledge and specific means which can help to lessen the seriousness of these widespread effects. Knowing the radiation level in his area, the farmer can take several protective and remedial measures.

Shelter

The most vitally important measure for the protection of farm families in time of emergency is to seek shelter quickly and stay there as long as possible. The interval between a warning of possible attack or the explosion and arrival of fallout may provide the time to get the family and livestock under cover. By taking advantage of the protection of shelter, many families and their livestock could escape injury or death.

Food, Feed, and Water

By protecting a sufficient quantity of food, feed, and water from fresh fallout contamination, farm families can prevent early internal radiation damage when the intensity is at high levels.

Maximum Work Times

Farmers who observe the maximum work times suggested for alternating shelter and out-of-doors work periods can gradually assume duties and still take advantage of recommended protection against radiation injury.

Food Decontamination

Some of the food that has been contaminated can be made safe for consumption by following suggested methods for decontamination or by allowing time for sufficient decay of radioactivity. Such food could be used for farm families, the community, or salvaged for market.

Reclaiming the Soil

Some contaminated farm land could be maintained in production by diverting it to its safest use, or by decontamination through the method best suited to the conditions.

These, then, are some of the safeguards available now against fallout damage. Research in radioactive fallout is being continued. New knowledge is expected to lead to improved methods of protecting American agriculture against hazards of fallout in time of emergency.

Glossary

(Definition of terms as they are used in this report)

ACCUMULATED DOSE: The total radiation dose resulting from repeated or prolonged exposure.

ACUTE EXPOSURE: Severe radiation exposure of short duration.

ADSORPTION: The adhesion of one substance to the surface of another.

AIR BURST: The explosion of a nuclear weapon at such a height that the expanding fireball does not touch the earth's surface at its greatest brilliance.

ATMOSPHERE: The entire envelope of air surrounding the earth.

ATOM: The smallest particle of an element that still retains the characteristics of that element.

ATTENUATION (RADIATION): The absorption and reduction of radiation intensity as it passes through any material.

BACKGROUND RADIATION: Nuclear radiation arising from within the body and from the surroundings to which individuals are always exposed in normal living. The main sources of natural background radiation are potassium 40 in the body and potassium 40, thorium, uranium, and radium present in rocks and cosmic rays.

BETA RAY: A minute, high speed particle with a negative charge which originates in the nucleus of certain radioactive elements.

BLAST: The effect in air of the liberation of a large amount of energy in a short interval of time within a limited space. The liberation of this energy is accompanied by a great increase in temperature creating extremely hot gases from the products of an explosion. These gases move outward rapidly, pushing away the surrounding air with great force and cause destructive effects of an explosion.

CELL: The fundamental unit of structure and function in plant and animal organisms.

CONTAMINATION (RADIOACTIVE): The deposit of radioactive material on the surface of soil, structures, objects, human beings, animals--entire areas--following a nuclear explosion. Food may also be further contaminated by absorbing radioactive material from contaminated soil or water.

COSMIC RAY: Any of the rays of extremely high energy and penetrating power produced, it is believed, by electric action in interstellar space (beyond the earth's atmosphere). They bombard the earth with radioactivity from all directions.

CURIE: A unit for measuring radioactivity, equal to that produced by a gram of radium. (Microcurie is one-millionth of a curie, and a micro-microcurie is one-millionth of a millionth of a curie.)

DECAY (RADIOACTIVE): The decrease in activity of any radioactive material with the passage of time. See: HALF-LIFE.

DENIAL TIME: The period of time persons would be prohibited because of radiation intensity from entering a contaminated area or leaving shelter in such an area. Also, the period of time croplands would be prohibited from use for designated agricultural products because of radioactive contamination, or milk prohibited from human consumption because of radioiodine content.

DISCRIMINATION FACTOR: The natural discrimination against strontium in favor of calcium by the biological systems of plants, animals, and man.

DOSE RATE: The amount of ionizing radiation to which an individual is exposed per unit of time (hour, day, week, or month.) It is usually expressed as the number of roentgens per hour. The dose rate is also commonly used to indicate the level of radiation intensity in a contaminated area.

DOSIMETER: An instrument for measuring and registering total accumulated exposure to ionizing radiation. It is commonly used to monitor personnel whose work could be expected to expose them to radiation.

ELECTRON: A very small particle of matter carrying a negative charge. Electrons are present in all atoms surrounding the nucleus. Their number is equal to the number of positive charges (or protons) in the particular nucleus.

ELEMENT: One of the distinct, basic varieties of matter existing in nature which, individually or in combination, compose all substances of all kinds. Ninety-two different elements have been identified in nature and about 10 others have been produced as a result of nuclear reactions.

EXTERNAL RADIATION: Radiation from a source external to the body.

FALLOUT: Very fine, dustlike particles of radioactive matter created by a nuclear explosion. The term is also used to describe the process of the fall back to the earth of the contaminated particles from the bomb cloud.

FIREBALL: The luminous sphere of hot gases which forms a fraction of a second after a nuclear explosion and immediately starts to expand and cool.

FISSION (NUCLEAR FISSION): The process in which the nucleus of an atom of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of large amounts of energy.

FISSION PRODUCTS: A general term for the complex mixture of radioactive substances produced as a result of nuclear fission. (The mixture contains about 200 different isotopes of over 30 elements.)

FOOD CHAIN: The movement of nutrients from the soil through plants and animals, and through the biological system of man as human nutrition.

GAMMA RAYS: Radiation of high energy emitted by the nucleus of an atom. These rays accompany many nuclear reactions including nuclear fission. Physically, gamma rays are identical with X-rays of high energy. The only essential difference is that X-rays do not originate in the nucleus of an atom.

GEIGER COUNTER: An instrument for measuring radiation dose rate. It is a highly sensitive instrument with a very short range of measurement, and would be useful only for monitoring low levels of intensity such as for food, water, and personnel.

GENETICS: The branch of biology dealing with heredity and variations of species from one generation to another.

HALF-LIFE: Time required for a radioactive substance to lose 50 percent of its radioactivity by decay.

HALF-VALUE LAYER: The thickness of any particular material necessary to reduce the intensity of gamma rays to one-half the original value.

HIGH-RANGE BETA-GAMMA SURVEY METER: An instrument for measuring radiation dose rate. It has a wide range of measurement and would be useful for monitoring areas with a high level of contamination.

INITIAL RADIATION: Nuclear radiation emitted from the fireball and atomic cloud during the first minute after a nuclear explosion.

INTENSITY (RADIATION): The term is used loosely to express the exposure dose rate of radiation at a given location. For example, the intensity of radiation in an area could be expressed in the number of roentgens per hour that is being received.

INTERNAL RADIATION: Nuclear radiation resulting from radioactive particles in the body. Internal radiation from fallout is caused largely by consuming contaminated food, water, and feed. In the early stages of fallout some internal radiation can be caused by inhaling the radioactive particles.

ION: An electrically charged particle of matter, either positive or negative.

IONIZATION: The process by which a neutral particle of matter receives an electrical charge, either positive or negative.

IONIZING RADIATION: Radiation capable of producing electrically charged particles (ions) either directly or indirectly as it passes through matter.

IRRADIATION: Exposure to radiation.

ISOTOPES: Forms of the same element which have identical chemical properties but which differ in their atomic masses (because they have a different number of neutrons in their respective nuclei). They may be stable (non-radioactive) or they may be radioactive.

KILOTON NUCLEAR BOMB: A nuclear bomb which produces the same amount of energy as 1,000 tons of TNT.

MAXIMUM PERMISSIBLE EXPOSURE: The total amount of ionizing radiation exposure which it is believed a normal person may receive day-by-day without harmful effects becoming evident during his lifetime.

MEDIUM-RANGE GAMMA SURVEY METER: An instrument for measuring radiation dose rate. It has a medium range of measurement and would be useful for ground survey where the radiation levels would be expected to change relatively slowly.

MEGATON NUCLEAR BOMB: A nuclear bomb which produces the same amount of energy as 1,000,000 tons or 1,000 kilotons of TNT.

MIDLETHAL DOSE (MEDIAN LETHAL DOSE, OR MLD): The amount of ionizing radiation over the whole body which is expected would be fatal to 50 percent of living creatures or organisms within 30 days. It is commonly (although not universally) accepted that 450 roentgens is the midlethal dose for human beings.

NEUTRON: A neutral particle of matter (with no electrical charge) present in all atomic nuclei except those of ordinary hydrogen. Neutrons are required to initiate the fission process, and large numbers of neutrons are produced in nuclear explosions.

NUCLEAR RADIATION: Radiation emitted from atomic nuclei in various nuclear processes. The types of radiation discussed in this report are beta rays and gamma rays. (Other radiations important in the results of nuclear explosions are alpha rays and neutrons.) All nuclear radiations are ionizing radiations, but the reverse is not true. For example, X-rays are ionizing radiations, but they are not nuclear radiations because they do not originate in the nucleus of an atom. See: IONIZING RADIATION.

NUCLEAR WEAPON (OR BOMB): A general name given to any weapon in which the explosion results from the energy released by reactions involving the nuclei of atoms. Thus, both atomic bombs and hydrogen bombs are in fact nuclear weapons, and the term is used to include both types in this report.

NUCLEUS (OR ATOMIC NUCLEUS): The central region of an atom that carries most of the mass and the total positive electrical charge. All atomic nuclei (except ordinary hydrogen) contain both protons and neutrons (positively charged and neutral particles). The electrons (negatively charged particles) of an atom are outside the nucleus.

PROTON: A particle of matter carrying a positive charge. It is identical physically with the nucleus of the ordinary hydrogen atom. All atomic nuclei contain protons.

RAD: A unit for measuring an absorbed dose of radiation.

RADIATION: See: NUCLEAR RADIATION.

RADIATION SICKNESS: A disease resulting from excessive exposure of the whole (or a large part) of the body to ionizing radiation. The earliest of these symptoms are nausea, vomiting, and diarrhea, which may be followed by loss of hair, hemorrhage, inflammation of the mouth and throat, and general loss of energy. In severe cases, where the radiation exposure has been relatively large, death may occur within 2 to 4 weeks. Those who survive 6 weeks after the receipt of a single dose of radiation may generally be expected to recover.

RADIOACTIVITY: The spontaneous disintegration or nuclear change of certain atoms in which energy is released. The process is accompanied by the emission of one or more types of radiation, such as beta and gamma rays.

RADIOIODINE (RADIOACTIVE IODINE): Iodine in which the nuclei of the atoms emit radiations.

RADIOSTRONTIUM (RADIOACTIVE STRONTIUM): Strontium in which the nuclei of the atoms emit radiations.

RATE METERS: Instruments used to measure radiation rates in an area.

RESIDUAL RADIATION: Nuclear radiation, chiefly beta and gamma rays, which persists for some time following a nuclear explosion. The radiation is emitted mainly by the fission products and other bomb residues in the fallout.

ROENTGEN: A unit for measuring a radiation exposure dose.

SHELTER: A specially constructed refuge, or the use of normal buildings or materials for the purpose of protecting people, livestock, food, feed, or water from the direct effects of fallout.

SHIELDING: Any material or obstruction which absorbs radiation and thus helps to protect people and livestock from the effects of radioactive fallout. A considerable thickness of material of high density may be needed.

STRATOSPHERE: The upper part of the earth's atmosphere, beginning approximately 7 miles above the earth.

SURFACE BURST: The explosion of a nuclear weapon at the surface of the earth, or at a height above the surface close enough for the fireball to touch the land or water. The effect of fallout is most serious following a surface burst.

TROPOSPHERE: The lower part of the earth's atmosphere, ending approximately 7 miles above the earth.

UNDERGROUND BURST: The explosion of a nuclear weapon with its center beneath the surface of the ground.

UNDERWATER BURST: The explosion of a nuclear weapon with its center beneath the surface of the water.

Appendix[1]

SHELTER RESERVE FOOD SUPPLY

Select foods that store easily, keep for months without refrigeration, are easily prepared, and require little or no cooking.

Foods canned in metal and glass will stay in good condition for 6 or more months if kept in a dry place, protected from sun and dust, and kept at a fairly cool temperature--preferably not above 70° F. or below freezing. To keep food in paper boxes as long as 6 months, place them in tightly closed metal cans or cabinets and store them under the dry, cool, clean conditions specified for canned foods, so that rodents and insects are not likely to attack them.

It is good practice to rotate foods in cans at least once or twice a year and foods in paper boxes (without added protection) at least every 3 months. This will ensure having a reserve supply of food that is good tasting. As food on the reserve shelf is used for meals for unexpected company and the family, replace it, putting the older stocks in front of the new supply.

If required, include special milk or strained, chopped, or other special foods for infants, toddlers, older persons, diabetics, invalids, and others on a special diet.

Cans and jars in sizes which will meet family needs for only one meal each are best for meat, poultry, fish, vegetables, fruit, evaporated milk, and other foods which deteriorate rapidly, unless refrigerated, after the container is opened. This also helps to eliminate the problem of leftovers.

The quantities of food shown in the following "Guide for Shelter Reserve Food Supply" are sufficient for one adult for 2 weeks. Choose the kinds of food that fit the needs and preferences of family members. If the family consists of four adults with moderate food needs, store 4 times the amount of food suggested in the guide. Teenagers may need as much or more food and young children may need less food than the amounts given in the guide.

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[1] From Advisory Bulletin No. 234, Office of Civil Defense Mobilization, March 30, 1959.

Kind of food	Need per person		Remarks
	Daily	2 weeks	
1. Milk	Equivalent of 2 glasses (fluid)	Equivalent of 7 quarts (fluid)	Each of the following is about equivalent of one quart of fluid milk: Three 6-ounce cans of evaporated milk. One 14 1/2-ounce can of evaporated milk. Three to 3 1/2-ounces of nonfat dry milk.
2. Canned meat, poultry, fish, dry beans and peas	2 servings	28 servings (about 8 to 9 pounds)	Amounts required for one serving of each food are as follows: Canned meat, poultry, fish--2 to 3 ounces. Canned mixtures of meat, poultry, or fish with vegetables, rice, macaroni, spaghetti, noodles, or dry beans--8 ounces. Thick soups, containing meat, poultry, fish, or dry beans or peas--one-half of a 10 1/2-ounce can (condensed).
3. Fruits and vegetables	3 to 4 servings	42 to 56 servings (about 21 pounds canned)	Amounts required for one serving of each food are as follows: Canned juices--4 to 6 ounces, single strength. Canned fruit and vegetables--4 ounces. Dried fruit--1 1/2 ounces.
4. Cereals and baked goods	3 to 4 servings	42 to 56 servings (about 5 to 7 pounds)	Amounts required for one serving of each food are as follows (selection depends on extent of cooking possible): Cereal: Ready-to-eat puffed--1/2 ounce. Ready-to-eat flaked--3/4 ounce. Other ready-to-eat and uncooked--1 ounce. Crackers, cookies--1 ounce. Canned bread, steamed puddings, and cake--1 to 2 ounces. Flour, flour mixes--1 ounce. Macaroni, spaghetti, noodles: Dry--3/4 ounce. Cooked, canned--6 ounces.

--Continued.

Table 1.--Guide for Shelter Reserve Food Supply--Continued

Kind of food	Need per person		Remarks
	Daily	2 weeks	
5. Spreads for bread and crackers	According to family practices		Examples: Cheese spreads Peanut and other nut butters Jam, jelly, marmalade, preserves Sirup, honey Apple and other fruit butters Relish, catsup, mustard
6. Hydrogenated fats and vegetable oil		Up to 1 pound or 1 pint	The amount needed depends on extent of cooking possible.
7. Sugars, candy, nuts, instant puddings		1 to 2 pounds	
8. Miscellaneous	According to family practices		Examples (amount needed depends on extent of cooking possible): Coffee, tea, cocoa Instant, dry cream substitute Bouillon products Synthetic beverage products Salt and spices (e.g., pepper) Flavoring extracts, vinegar Soda, baking powder
9. Water	1/2 gallon	7 gallons	

Publications and Films

Publications

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Defense Against Radioactive Fallout on the Farm. Farmers' Bulletin No. 2107, Slightly Revised September 1959.

Films*

Fallout. Color or B&W; time: $14\frac{1}{2}$ min. Released March 1959.

Mission Fallout. Color; time: 45 min. Released March 1959.

Operation Ivy. Color or B&W; time: 28 min. Released March 1954.

Rural Community Defense. B&W; time: $13\frac{1}{2}$ min. Released November 1959.

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*Prints available from OCDM, Battle Creek, Mich.

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